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DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 57

PRELIMINARY LIST OF DEEP BORINGS IN THE UNITED STATES, PART I (ALABAMA–MONTANA).—Darton

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 120 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888-89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Published as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 63 plates and 109 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 83, Irrigation in Arizona; No. 90, Irrigation in New Mexico; No. 81, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 133, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 160, Irrigation in Nevada; No. 175, Irrigation in Oregon; No. 195, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 29, September 9, 1892; quarto, 29 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a resume of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891-92. Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; and "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 47 plates and 120 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892-93, in two parts; Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; and "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 57

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

PRELIMINARY LIST

OF

DEEP BORINGS IN THE UNITED STATES

PART I

(ALABAMA-MONTANA)

BY

N. H. DARTON

WASHINGTON

GOVERNMENT PRINTING OFFICE

1902

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., July 31, 1901.

SIR: I have the honor to transmit herewith a preliminary list of deep borings in the United States (400 feet or more in depth), by Mr. N. H. Darton, with the request that it be published in the series of Water-Supply and Irrigation Papers.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

PRELIMINARY LIST OF DEEP BORINGS IN THE UNITED STATES.

PART I.—ALABAMA-MONTANA.

By N. H. DARTON.

INTRODUCTION.

The wells and borings reported in the paper are all more than 400 feet in depth. The information concerning them has been obtained partly from replies to circular letters sent to all parts of the United States and partly from geological reports and other published sources. Owing to the difficulty of obtaining replies to the circulars, to lack of knowledge on the part of correspondents, and to the incompleteness of published records, doubtless there are borings which have not been reported. In regions of oil and gas wells, where borings are numerous, the individual wells can not be listed here, but representative wells are given. References to logs or records of the wells, or extended descriptions of them, are given in footnotes, and after the list of wells in each State there is added a list of the principal publications relating to deep borings in that State.

The bearing of the information given in the columns of the lists probably is apparent, unless, perhaps, in the one headed "Height to which the water rises." In this column an entry such as "—45" indicates that the water rises to within 45 feet of the surface; "+45" indicates that it is a flowing well and has sufficient head to raise the water 45 feet above the surface in an open pipe 45 feet or more in height. The yield in gallons per minute usually is estimated. Depths and diameters often have been reported from memory, and different sources of publication sometimes give different figures. Most wells which are not stated to be "for oil," "for gas," "brine," "abandoned," etc., in the remarks column, or "not any" in the yield column, generally afford more or less water. Many of the gas and oil wells, active or abandoned, yield salt water.

ALABAMA.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Anniston	Calhoun	400–550	8	695	− 30	Several wells.
Armstrong	Macon	442				Good water.
Birmingham	Jefferson	550		70	− 30	
Bladen Springs	Choctaw	1,300			+ 70	Water salt; first flow at 200 feet, second flow at 600 feet.
Boguechitto	Dallas	±400		0¼		In sec. 8, T. 18, R. 8 E.
Do	do	460	6	75	+ 25	Temp., 68°.
Boligee.[1]	Greene	415			Flows.	Temp., 68°.
Do.[1]	do	420			Flows.	Temp., 66°.
Do.[1]	do	498			Flows.	Temp., 66¼°.
Do.[1]	do	522			Flows.	Temp., 70°.
Boligee (at Finche's ferry).[1]	do	560			Flows.	Temp., 71°.
Brantley	Crenshaw	600	4			Good flow; 2 wells.
Bughall	Bullock	920				Unsuccessful.
Burton Hill[1]	Greene	544				Temp., 70°.
Do.[1]	do	420				
Do.[1]	do	555				Temp., 75°.
Butler	Choctaw	660			− 30	
Cahaba[1]	Dallas	400				Temp., 73¼°.
Cahaba (on river)[1]	do	590	6	80	22	Temp., 70°.
Cahaba (5 miles below).[1]	do	560		[2]250		Two wells.
Cahaba[1]	do	728		1,200		Temp., 77¼°.
Carpenter	Jackson	400				Unsuccessful.
Cullman	Cullman	700				City well.
Demopolis	Marengo	765	3	30	+ 20	Temp., 64°.
Do	do	735	4	15	+ 12	
Do	do	850	6¼	60	Flows.	
Do	do	800	3	Many.	+ 52	
Demopolis (3 miles south).	do	1,350		Many.	− 30	
Demopolis (4 miles northeast).	do	500		200	Flow.	Several wells.
Dothan	Henry	625	8		−150	
Epes	Sumter	700		3	+ 1¼	
Eutaw[1]	Greene	743			− 10	
Eutaw (10 miles southwest).[1]	do	440–550				Temp., 71°-72¼°; four wells.
Faunsdale	Marengo	700		8	+ 2¼	
Fayette	Fayette	500			− 30	
Fitzpatrick	Bullock	900	6		− 30	
Do	do	1,300	6	12	− 30	
Florence	Lauderdale	+400				For gas; unsuccessful.
Forkland	Greene	575		20	+ 3	
Fort Morgan		700				
Greensboro	Hale	400–800		Many.	− 30	Several wells; good water.
Do	do					
Do	do	1,000				
Greensboro (10 miles southwest).	do	450 or 850	12	Many.		
Greenville	Butler	+400	10–8	100	− 30	Two wells.
Guntersville	Marshall	1,000	8–6			Temp., 60°.
Hairston	Greene	530		4	+ 2¼	2¼ miles east.
Hanover (?)	Coosa	480	4		− 40	
Harris	Barbour	700				
Do	do	780	3			Abandoned; milky water at 140 feet to −15 feet.
Hartsell[3]	Morgan	1,730	2			1 mile north of town: salt water at 352 and 1,730 feet; gas at 602 and 1,094 feet; sulphur water at 160 feet.
Hatchechubbee	Russell	420		8	No flow.	Small supply of water at 250 feet.
Hunters Field	Dallas	550	5	70	− 18	
Hurtsboro	Russell	530	4	±10	− 9	
Do	do	550	3	±11	− 9	
Do	do	565	3	±12	− 23	
Jennings (3 miles southeast).[4]	Lawrence	5,120	6			Gas, oil, and salt water.

[1] Record, Am. Assoc. Adv. Science, Proc., vol. 10, p. 95.
[2] Each.
[3] Alabama Geol. Surv., Report on Valley Regions, Part 1, pp. 62–63.
[4] Ibid., pp. 61–62.

ALABAMA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Laneville	Hale	710			Flow.	Temp., 75°.
Do	do	719			Flow.	Temp., 76°.
Do	do	750				In progress.
Larkinsville	Jackson	400				Unsuccessful.
Linden	Marengo	1,193		1	Flows	Water at 1,040 to 1,115 feet.
Mobile	Mobile	700	6	400		Temp., 76°.
Do	do	735		Many.	+ 90	Temp., 78°.
Do	do	800	6	500		Temp., 76°.
Do	do	800	6	1,000	+ 70	Temp., 78°.
Do	do	850				
Montgomery	Montgomery	650–450	6	974–200	− 60	Four wells; originally flowed to +20 feet.
Newbern	Hale	475		30	+ 4	
Newmarket[1]	Madison	965	2		Flows.	
Oneonto	Blount	600				
Roba	Macon	450				Good water supply.
Russellville	Franklin	+1,350				2 miles east; unsuccessful.
Saint Elmo	Mobile	550				
Selma[2]	Dallas	409		230		Temp., 67½°.
Do	do	470	6			Temp., 72°.
Do	do	600	6	80	+ 16	Do.
Do	do	487	6	110	+ 28	Temp., 68°.
Do	do	650		100	+ 40	Four wells.
Sledges		490	4	Many.	− 60	
Sprague Junction	Montgomery	400	8–6		− 75	
Stewart	Hale	600			+ 8	
Tank Station	Dallas	560	6	90	+ 35	Temp., 70°.
Town Creek[3]	Lawrence	515				Abandoned.
Troy	Pike	2,700				Unsuccessful.
Tuskegee	Macon	500	6			Do.
Do	do	760	8			Do.
Union Springs	Bullock	1,000		Many.		
Do	do	848½	6–2½	60		
Do	do	848½	8	150	−240	
Do	do	569		Many.		Good water.
Do	do	750		Many.		Do.
Uniontown	Perry	895	8		−125	
Do	do	1,195	8	300	−120	Water from 870 feet.

ARIZONA.

Ash Fork	Yavapai	1,025	10	No water.		In volcanic rock.
Aubrey	do	936	12–8	No water.		
Drake	Mohave	488	10			In progress.
Florence	Pinal	413	6	Few.		Well never used.
Gila Bend	Maricopa	1,300			−700	
Haviland	Mohave	600	10	Many.		
Kingman	Mohave	900 1,100		No water.		60 miles north.
Mohawk	Yuma	1,100	5½–4½			3 wells.
Do	do	500		28		
Phoenix	Maricopa	750	5		− 20	Abandoned.
Do	do	475				
Do	do	1,420				
Do	do	1,475				
Phoenix (12 miles west.)	do	500				Not completed.
Pima	Graham	420				Unsuccessful.
Safford	do	500			No flow.	
Sentinel	Maricopa	1,029	5	50	−185	
Thatcher	Graham	430		Few.	No flow.	
Wickenburg, northwest of.	Maricopa	400				No good results.
Winslow	Navajo	1,700				No fresh water.
Yucca	Mohave	534			−325	Satisfactory water supply.

[1] Record, Alabama Geol. Surv., Report on Valley Regions, Part 1, p. 127.
[2] Record, Am. Assoc. Adv. Science, Proc., vol. 10, pp. 97–98.
[3] Record, Pa. 2d Geol. Surv., Report II, p. 283.

ARKANSAS.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Arkansas City	Desha	552	6	Many.	.....	Temp., 72°.
Bowen	Pike	400	.....	Many.	No flow.	Several wells of this kind in county.
Fayetteville[1]	Washington	1,480	.....	.....	.....	
Forrest City	St. Francis	465	4	Many.	.....	
Do	do	465	6	Many.	.....	
Gentry	Benton	492	8–6¼	420	− 19	
Do	do	±700	.....	.....	No flow.	
Do	do	1,000	7	.....	− 30	Water at 700 and 900 feet.
Do	do	±1,350	.....	.....	.....	
Helena	Phillips	500	12	Many.	.....	Two wells.
Hope	Hempstead	500	.....	.....	− 60	
Hot Springs	Garland	860	6	13	.....	
Hudson	Little River	900	.....	.....	.....	
Do	do	800	4	Many.	No flow.	
Huntington	Sebastian	501	5¼	.....	− 60	Water from 169 feet.
Monticello	Drew	500	8	.....	−125	
Do	do	604	8–4¼	100	−110	
Mena	Polk	+700	10	Many.	No flow.	
Magazine	Logan	1,800	.....	.....	.....	
Pine Bluff	Jefferson	915	8	521	− 30	Two wells.
Do	do	840	10	185	− 20	
Prescott (12 miles south).	Nevada	400–450	.....	.....	Flow.	Several wells.
Saline Landing[2]	Howard	466	.....	.....	.....	
Texarkana	Miller	937	6	209	To surface.	
Washington	Hempstead	750	3	.....	− 35	Weak vein of water at 104 feet.
Wilmer	Drew	400	.....	.....	.....	
White Cliffs	Sevier	460	.....	.....	+ 25	
Do	do	450	.....	.....	+ 8	Temp., 65°.
Do	do	540	.....	.....	− 60	Temp., 64°.

CALIFORNIA.

Adams Canyon[3]	Ventura	400–2,780	.....	.....	.....	Many oil wells, yielding 900 barrels per month.
Alameda	Alameda	489	.....	.....	Surface.	
Do.[4]	do	409	.....	.....	− 8	
Alhambra	Los Angeles	400	7	.....	.....	Oil well.
Alila[5]	Tulare	1,328	9	.....	+ .25	Small flow of gas.
Aliso Canyon	Ventura	600–700	.....	.....	.....	Several oil wells.
Arcade	Sacramento	2,160	.....	.....	.....	
Atwater	Merced	400	7	5	.....	
Auburn	Placer	730	.....	.....	.....	
Alviso	Santa Clara	496	7	.....	+ .5	
Do	do	740	7	.....	+1.2	
Do	do	550	7	.....	Flows.	
Bakersfield	Kern	480	8	30	Flows.	
Do	do	500	8	300	Flows.	
Do	do	1,100	.....	480	Flows.	
Do	do	600	8	30	Flows.	
Do	do	400	8	1,500	Flows.	
Beckwith	Plumas	400	3	80	Flows.	
Do	do	500–800	3	100	Flow.	Numerous wells.
Do	do	1,000–1,200	2–3	Many.	Flow.	
Beckwith (8 miles above).	do	900	3	Many.	.....	Very warm mineral water.
Bieber	Lassen	740	4	.....	.....	
Bishop	Inyo	420	.....	.....	.....	In progress.
Brownstone	Ventura	400–800	.....	.....	.....	Several wells.
Buckhorn Station (4 miles north).	.....	400	.....	.....	.....	Oil well.
Buena Vista	Kern	410	.....	.....	.....	Oil at 392 feet.
Carpinteria (2 miles from).[6]	Santa Barbara.	700	.....	.....	.....	Oil and gas well.

[1] Record, Arkansas Geol. Surv., Report, vol. 2, 1891, pp. 67–69.
[2] Id., vol. 1, 1891, p. 105.
[3] Cal. State Mining Bureau, Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, pp. 35–36.
[4] Record, Cal. State Mining Bureau, 11th Rept., 1891–92, pp. 135–136.
[5] Cal. State Mining Bureau, 11th Rept., 1891–92, p. 488.
[6] Id., 12th Rept., 1893–94, p. 357.

CALIFORNIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Cedarville	Modoc	433			No flow.	
Centerville	Alameda	442			Flows.	
Chico [2]	Butte	698		Several	No flow.	
Chino (about 2½ miles northwest).	San Bernardino.	609				Abandoned.
Chittenden	Santa Cruz	800				For oil.
Clearwater (?)	Los Angeles	465		Many.		
Coalinga [1]	Fresno	400–650				Numerous oil wells in two groups, one 3 miles west, the other 9 miles north.
Crows Landing	Stanislaus	408	8	2	Flows(?)	
Cutler Salmon Ranch	San Joaquin	1,250	7–4			Gas well.
Danby	San Bernardino.	630	10	50	−200	
Delano	Kern	713	15	3,470	Flows.	
Delano (5 miles southwest).	do	822			− 3	
Dos Palos	Merced	442–550				Several wells.
Downey	Los Angeles	412	2	60		
Eagleville	Modoc	503	4½			
El Verano [2]	Sonoma	544			No flow.	
Embarcadero [3]	do	405			+ 15	
Ethel		442	10	Many.	To surface.	
Fairview	Orange	450	7			
Fenner	San Bernardino.	800	10	Many.	−200	
Fitchburg [4]	Alameda	400–500	7–12	1,000	No flow.	Several wells.
Flowing Well	San Diego	±400				
Four Forks [5]	Ventura	700–1,100				Several oil wells.
Fresno	Fresno	575				
Garvanza (west of)	Los Angeles	985				For oil; unsuccessful.
Glendora	do	2,038	5½		No flow.	
Grafton	Yolo	450	6	Many.		
Grangeville	Tulare	980	7		−.10	
Hanford [6]	Kings	500–800	9–7	100–400	Flow.	Numerous wells.
Do	do	1,300				
Irvington	Alameda	450			Flows.	
J. G. James' ranch	Fresno	600–800	7–8	Flows.	+ 3	Several wells. Temp., 60°.
Kentuck	Ventura	700–730				Several oil wells.
Kingsburg	Fresno	600			No flow.	
Lathrop Junction	San Joaquin	1,420	8		Flows.	Gas well.
Limekiln Canyon	Tulare (?)	500				Oil well.
Little Sespe District	Ventura	805				Do.
Long Beach	Los Angeles	500	8	1,100	Flows.	
Do	do	460	9–7	Many.	Flows.	
Los Angeles [7]	do	450–1,300				Numerous oil wells, some abandoned.
Los Angeles (The Ivanhoe). [8]	do	+1,000				Small supply of oil, abandoned.
Los Angeles (United States Hotel). [9]	do	+ 900				Gas at 900 feet.
Los Angeles (Stewart and McFarland). [10]	do	1,485				For oil; unsuccessful.
Los Angeles (Angelina Heights). [11]	do	1,186				For oil or gas; abandoned.
Los Angeles (Boyle Heights).	do	600				For oil; unsuccessful.
Los Angeles (Dr. Long's ranch).	do	500	7			Small supply of oil; abandoned.
Los Angeles (Lookout Mountain).	do	550				Do.
Los Angeles (few miles southeast).	do					Gas well.
Los Angeles (4 miles northwest). [12]	do	820				Small supply of oil.

[1] Analysis, Cal. State Mining Bureau, 12th Rept., 1893-94, pp. 352–353.
[2] Record, Cal. State Mining Bureau, 11th Rept., 1891-92, p. 457.
[3] Record, ibid., p. 457.
[4] Cal. State Mining Bureau, 11th Rept., 1891-92, p. 134.
[5] Id., Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, p. 27.
[6] Cal. State Mining Bureau, 11th Rept., 1891-92, p. 489.
[7] Cal. State Mining Bureau, Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, pp. 14–17.
[8] Ibid., p. 14.
[9] Ibid., p. 17.
[10] Cal. State Mining Bureau, 7th Rept., 1887, p. 78.
[11] Cal. State *Mining Bureau, Bull.* No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, *and Santa Barbara counties*, part 1, p. 14.
[12] *Cal. State Mining Bureau*, 7th Rept., 1887, p. 77.

ARKANSAS.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Arkansas City	Desha	552	6	Many.	.....	Temp., 72°.
Bowen	Pike	400	.....	Many.	No flow.	Several wells of this kind in county.
Fayetteville[1]	Washington	1,480	.....	.....	.....	
Forrest City	St. Francis	465	4	Many.	.....	
Do	do	465	6	Many.	.....	
Gentry	Benton	492	8-6¼	420	− 19	
Do	do	±700	.....	.....	No flow.	
Do	do	1,000	7	.....	− 30	Water at 700 and 900 feet.
Do	do	±1,350	.....	.....	.....	
Helena	Phillips	500	12	Many.	.....	Two wells.
Hope	Hempstead	500	.....	.....	− 60	
Hot Springs	Garland	860	6	13	.....	
Hudson	Little River	900	.....	.....	.....	
Do	do	800	4	Many.	No flow.	
Huntington	Sebastian	501	5¼	.....	− 60	Water from 169 feet.
Monticello	Drew	500	8	.....	−125	
Do	do	604	8-4¼	100	−110	
Mena	Polk	+700	10	Many.	No flow.	
Magazine	Logan	1,800	.....	.....	.....	
Pine Bluff	Jefferson	915	8	521	− 30	Two wells.
Do	do	840	10	185	− 20	
Prescott (12 miles south).	Nevada	400-450	.....	.....	Flow.	Several wells.
Saline Landing[2]	Howard	466	.....	.....	.....	
Texarkana	Miller	937	6	209	To surface.	
Washington	Hempstead	750	3	.....	− 35	Weak vein of water at 104 feet.
Wilmer	Drew	400	.....	.....	.....	
White Cliffs	Sevier	460	.....	.....	+ 25	
Do	do	450	.....	.....	+ 8	Temp., 65°.
Do	do	540	.....	.....	− 60	Temp., 64°.

CALIFORNIA.

Adams Canyon[3]	Ventura	400-2,780	.....	.....	.....	Many oil wells, yielding 900 barrels per month.
Alameda	Alameda	489	.....	.....	Surface.	
Do.[4]	do	409	.....	.....	− 8	
Alhambra	Los Angeles	400	7	.....	.....	Oil well.
Alila[5]	Tulare	1,328	9	.....	+ .25	Small flow of gas.
Aliso Canyon	Ventura	600-700	.....	.....	.....	Several oil wells.
Arcade	Sacramento	2,160	.....	.....	.....	
Atwater	Merced	400	7	5	.....	
Auburn	Placer	730	.....	.....	.....	
Alviso	Santa Clara	496	7	.....	+ .5	
Do	do	740	7	.....	+1.2	
Do	do	550	7	.....	Flows.	
Bakersfield	Kern	480	8	30	Flows.	
Do	do	500	8	300	Flows.	
Do	do	1,100	.....	480	Flows.	
Do	do	600	8	30	Flows.	
Do	do	400	8	1,500	Flows.	
Beckwith	Plumas	400	3	80	Flows.	
Do	do	500-800	3	100	Flow.	Numerous wells.
Do	do	1,000-1,200	2-3	Many.	Flow.	
Beckwith (8 miles above).	do	900	3	Many.	.....	Very warm mineral water.
Bieber	Lassen	740	4	.....	.....	
Bishop	Inyo	420	.....	.....	.....	In progress.
Brownstone	Ventura	400-800	.....	.....	.....	Several wells.
Buckhorn Station (4 miles north).	.....	400	.....	.....	.....	Oil well.
Buena Vista	Kern	410	.....	.....	.....	Oil at 392 feet.
Carpinteria (2 miles from).[6]	Santa Barbara.	700	.....	.....	.....	Oil and gas well.

[1] Record, Arkansas Geol. Surv., Report, vol. 2, 1891, pp. 67-69.
[2] Id., vol. 1, 1891, p. 105.
[3] Cal. State Mining Bureau, Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, pp. 35-36.
[4] Record, Cal. State Mining Bureau, 11th Rept., 1891-92, pp. 135-136.
[5] Cal. State Mining Bureau, 11th Rept., 1891-92, p. 488.
[6] Id., 12th Rept., 1893-94, p. 357.

CALIFORNIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Cedarville	Modoc	433			No flow.	
Centerville	Alameda	442			Flows.	
Chico [illegible]	Butte	698		Several	No flow.	
Chico (about 2½ miles northwest).	San Bernardino.	600				Abandoned.
Chittenden	Santa Cruz	800				For oil.
Clearwater (?)	Los Angeles	465		Many.		
Coalinga [1]	Fresno	400–650				Numerous oil wells in two groups, one 3 miles west, the other 9 miles north.
Crows Landing	Stanislaus	408	8	2	Flows(?)	
Cutler Salmon Ranch	San Joaquin	1,250	7–4			Gas well.
Danby	San Bernardino.	630	10	50	−200	
Delano	Kern	713	15	3,470	Flows.	
Delano (5 miles southwest).	do	822			− 3	
Dos Palos	Merced	442–550				Several wells.
Downey	Los Angeles	412	2	60		
Eagleville	Modoc	503	4½			
El Verano [2]	Sonoma	544			No flow.	
Embarcadero [3]	do	405			+ 15	
Ethel		442	10	Many.	To surface.	
Fairview	Orange	450	7			
Fenner	San Bernardino.	800	10	Many.	−200	
Fitchburg [4]	Alameda	400–500	7–12	1,000	No flow.	Several wells.
Flowing Well	San Diego	±400				
Four Forks [5]	Ventura	700–1,100				Several oil wells.
Fresno	Fresno	575				
Garvanza (west of)	Los Angeles	985				For oil; unsuccessful.
Glendora	do	2,038	5½		No flow.	
Grafton	Yolo	450	6	Many.		
Grangeville	Tulare	980	7		−.10	
Hanford [6]	Kings	500–800	9–7	100–400	Flow.	Numerous wells.
Do	do	1,300				
Irvington	Alameda	450			Flows.	
J. G. James' ranch	Fresno	600–800	7–8	Flows.	+ 3	Several wells. Temp., 60°.
Kentuck	Ventura	700–730				Several oil wells.
Kingsburg	Fresno	600			No flow.	
Lathrop Junction	San Joaquin	1,420	8		Flows.	Gas well.
Limekiln Canyon	Tulare (?)	500				Oil well.
Little Sespe District	Ventura	805				Do.
Long Beach	Los Angeles	500	8	1,100	Flows.	
Do	do	460	9–7	Many.	Flows.	
Los Angeles [7]	do	450–1,300				Numerous oil wells, some abandoned.
Los Angeles (The Ivanhoe). [8]	do	+1,000				Small supply of oil, abandoned.
Los Angeles (United States Hotel). [9]	do	+ 900				Gas at 900 feet.
Los Angeles (Stewart and McFarland). [10]	do	1,485				For oil; unsuccessful.
Los Angeles (Angelina Heights). [11]	do	1,186				For oil or gas; abandoned.
Los Angeles (Boyle Heights).	do	600				For oil; unsuccessful.
Los Angeles (Dr. Long's ranch).	do	500	7			Small supply of oil; abandoned.
Los Angeles (Lookout Mountain).	do	550				Do.
Los Angeles (few miles southeast).	do					Gas well.
Los Angeles (4 miles northwest). [12]	do	820				Small supply of oil.

[1] Analysis, Cal. State Mining Bureau, 12th Rept., 1893-94, pp. 352-353.
[2] Record, Cal. State Mining Bureau, 11th Rept., 1891-92, p. 457.
[3] Record, ibid., p. 457.
[4] Cal. State Mining Bureau, 11th Rept., 1891-92, p. 134.
[5] Id., Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, p. 27.
[6] Cal. State Mining Bureau, 11th Rept., 1891-92, p. 489.
[7] Cal. State Mining Bureau, Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, pp. 14-17.
[8] Ibid., p. 14.
[9] Ibid., p. 17.
[10] Cal. State Mining Bureau, 7th Rept., 1887, p. 78.
[11] Cal. State Mining Bureau, *Bull. No.* 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and *Santa Barbara counties*, part 1, p. 14.
[12] *Cal. State Mining Bureau, 7th Rept.*, 1887, p. 77.

CALIFORNIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Los Angeles (5½ miles west).[1]	Los Angeles	+ 500				Small flow of gas; abandoned.
Los Angeles (6 miles west).[1]	do	658-1,485				Two wells, for oil; unsuccessful.
Los Angeles (10 miles north of west).[2]	do	520				Two wells, sulphur water and some gas; abandoned.
Los Banos[3]	Merced	434			Flows.	
Loyalton	Sierra	525-750	4	50	Flow.	Several wells.
Do	do	1,000		20	Flows.	Temp. 130°.
Do	do	400	3	100	Flows.	
Do	do	620	4		Flows.	
Do	do	430-512	3	30	Flow.	Several wells.
Ludlow	San Bernardino.	1,800		Few.		Not in use.
Madera[4]	Madera	1,200			−3	
Do	do	680			+ ⅓	
Madera (6 miles west)	do	633	7	¼	Flows.	
Mayfield	Santa Clara.	604	7	100	Flows.?	
Merced	Merced	600-700	9	167-175		
Merced (13 miles southwest).	do	1,013	10		+ 1½	Strongest flow at 665 and 680 feet.
Milpitas	Santa Clara.	500-700	7		+ 2	Two wells.
Miramonte	Kern	636	8	1,670	Flows.	
Do	do	457	8			
Modesto (1 mile east)	Stanislaus	1,070		Many.	No flow.	Small flow of gas.
Montague[5]	Siskiyou	1,300	10-8			Gas well.
Moody Gulch[6]	Santa Barbara.	1,400				For oil or gas.
Mount Cayetana (southwest slope, near Santa Paula Creek).[7]	Ventura	430-1,170				Several oil wells.
Mount Diablo	Santa Barbara.	900				
Newman	Stanislaus	427	12		Flows.	
Do	do	445	8	1,250		
Newman Ranch	do	411	8		4½	Brackish water.
Nordhoff (1 mile south).	Ventura	500-800				Several oil wells.
Norman (2 miles north).[8]	Glenn	940	2	4	+15	Small amount of gas at 337 feet.
Norman (about ½ mile southeast).	do	1,100			Surface.	Small amount of gas at 500 feet.
North Cucamonga	San Bernardino.	450		Many.		
Norwalk	Los Angeles	480	4			
Oakland	Almeda	506		112	Flows.	
Ontario	do	457	9½		No flow.	
Oroville	Butte	800	3	4	Flows.?	
Pasadena	Los Angeles	1,200				No water.
Peru (1¼ miles south)	Ventura	400-570				Several oil wells.
Pico	Los Angeles	600-735				Numerous oil wells.
Pixley	Tulare	438	8	Many.		
Do	do	480	7	Many.	+ .1	
Do	do	600	8		+ .8	
Do	do	713	9		+ .3	
Do	do	730	8		+ .2	
Pixley (1½ miles northwest).[9]	do	955	9		+ .2	
Pixley (2 miles east)	do	600	8		.1	
Pixley (vicinity)	do	1,150	9	1,200	Flows.	
Do	do	937	9		+ .6	
Pixley (3 miles west)	do	858	8		+ .7	
Pixley	do	1,000	9		Flows.	
Pixley (3 miles southwest).	do	815	9		+ .2	
Pixley (6 miles southwest).[10]	do	1,150	9		+ 1	
Pixley (6 miles west)	do	950	8		+ 7	

[1] Cal. State Mining Bureau, Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, p. 15.
[2] Cal. State Mining Bureau, 7th Rept., 1887, p. 78
[3] Record, Cal. State Mining Bureau, 10th Rept., 1890, p. 326.
[4] Cal. State Mining Bureau, 11th Rept., 1891-92, p 211.
[5] Cal. State Mining Bureau, 12th Rept., 1893-94, p. 351.
[6] Record, Cal. State Mining Bureau, 8th Rept., 1888, p. 548.
[7] Record, Cal. State Mining Bureau, Bull No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, pp. 37-38.
[8] Record, Cal. State Mining Bureau, 11th Rept., 1891-92, p. 224.
[9] Cal. State Mining Bureau, 11th Rept., 1891-92, p. 487
[10] Ibid., *pp.* 487-488.

CALIFORNIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Pixley (10 miles southwest).[1]	Tulare	895	10		+4	
Pomona	do	450–550	6 and 9			
Potter Valley	Mendocino	400			−11	
Puente[2]	Los Angeles	100–1,750				Numerous oil wells.
Roberts Island	San Joaquin	1,435	7–5		Flows.	Gas well; saline water.
Riverside	Riverside	580	10	Many.	Flows.	
Rocky Point	Sierra	1,132	3	20	Flows.	
Do	do	1,040	4	10	Flows.	
Sacramento[3]	Sacramento	876				Gas well.
Do.[4]	do	965				Do.
Do.[4]	do	970			Flows.	Water salty and alkaline.
Sacramento (9 miles northeast).[5]	do	2,250			Flows.	Some gas.
St. Helena	Napa	2,000				
Salinas	Monterey	1,435	8		−6	
Do	do	1,100	11–9		−10	
Salt Marsh Canyon[6]	Ventura	400–1,600				Several oil wells.
San Bernardino	San Bernardino.	605	6	Many.	Flows.	
Do	do	425	3	76	Flows.	
Do	do	415	3	7	Flows.	
San Francisco	San Francisco	865	8–5	87		
San Gabriel	Los Angeles	500±	7			
San Jacinto	San Diego	456–650	7			Several wells.
San Jose	Santa Clara	442–700	7	Many.	Flow.	Do.
Do	do	400	8	400	Flows.	
San Lewis Ranch	Merced	410–426	7	128–160		Two wells.
San Louis Obispo	San Louis Obispo.	928		Many.	Flows.	For oil; unsuccessful. Sulphur water; temp., 103°; gas at 600 feet.
Santa Barbara (7 miles east).[7]	Santa Barbara.	400–1,000				Several oil wells; some abandoned.
Santa Clara	Santa Clara	600		Many.	+10	Temp., 60°.
Santa Paula region	Ventura	530–800				Several oil wells.
Santa Rosa (4 miles south).[8]	Sonoma	815		Few.		Flows at intervals.
Sattley	Sierra	625	2	1	Flows.	
Savilla Colony[9]		600		Many.	Flows.	Gas and sulphur water; gas not used.
Semitropic	Kern	495	8–7	Many.	Flows.	
Sheridan[10]	Placer	734			−19	
Sierra Valley	Sierra	640–888	3	15–45	Flow.	Several wells.
Do	do	556–900	4	125–300	Flow.	Do.
Do	do	746	2	16	Flows.	
Silverthread oil district (near Santa Paula Creek).[11]	Ventura	400–1,600				Numerous oil wells.
Sisi Canyon		400–800				Do.
Smyrna Colony	Kern	524–600				Two wells.
Stockton	San Joaquin	420	8		+ ½	Warm water.
Stockton (S. F. and S. J. V. R. R.)	do	497	7	Many.	−19	
Stockton[12]	do	1,002			+ 7	Temp., 77°.
Do	do	1,400–2,000				Gas wells.
Stockton (Jackson well).[13]	do	1,700	12–9½	Many.		Gas well.
Stockton[14]	do	1,400				Do.

[1] Cal. State Mining Bureau, 11th Rept., 1891-92, p. 488.
[2] Cal. State Mining Bureau, Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, pp. 18–21.
[3] Cal. State Mining Bureau, 12th Rept., 1893–94, p. 350.
[4] Ibid., p. 350.
[5] Record, Cal. State Mining Bureau, 10th Rept., 1890, p. 505.
[6] Cal. State Mining Bureau, Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, pp. 36–37.
[7] Cal. State Mining Bureau, 12th Rept., 1893–94, p. 357.
[8] Record, Cal. State Mining Bureau, 11th Rept., 1891-92, p. 456.
[9] Cal. State Mining Bureau, Bull. No. 3, Gas and Petroleum Yielding Formations of the Central Valley of California, p. 20.
[10] Record, Cal. State Mining Bureau, 11th Rept, 1891-92, p. 319.
[11] Cal. State Mining Bureau, Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, pp. 33, 35, 37.
[12] Record, Cal. State Mining Bureau, 8th Report, 1888, pp. 559–560.
[13] Record, Cal. State Mining Bureau, Bull. No. 3, Gas and Petroleum Formations of the Central Valley of California, p. 17.
[14] Ibid., p. 17.

CALIFORNIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Stockton Asylum (Jackson well).[1]	San Joaquin	600+-1,750	.....	Many.	.....	Two gas wells.
Stockton (St. Agnes College).[1]	....do	1,720	.....	Many.	.....	Do.
Stockton (courthouse).[2]	....do	1,917	12-8	Many.	.....	Gas well.
Stockton (Citizens' Gas Co.).	....do	2,061	.....	Many.	.....	Do.
Stockton	....do	980-1,080	.....	Many.	Flow.	Several wells; temp., 75°.
Stockton (9 miles southeast).	....do	1,404	7-5	Many.	.....	Some gas.
Summit	Plumas	400-800	3	5-125	Flow.	Numerous wells.
Do	....do	1,008	3-4	.....	Flow.	
Sunset District[3]	Kern	500-1,350	.....	.....	.....	Numerous oil and brine wells.
Susanville	Lassen	960	.....	.....	−10	
Tar Creek[4]	Ventura	700-1,000	.....	.....	.....	Numerous oil wells.
Tar Creek Canyon	....do	400-905	.....	.....	.....	Do.
Tipton	Tulare	400	7	.....	+.04	Several wells about the same depth.
Do	....do	480	8-6	.....	+.04	
Do	....do	503-1,012	8-9	Many.	Flow.	Several wells.
Torrey Canyon	Ventura	450-1,000	.....	Many.	Flow.	Oil wells.
Traver	Tulare	960	7	Few	.....	
Tulare	....do	400	6	.....	+.8	
Do	....do	460	7	500	.....	
Tulare (about 20 miles west).	....do	500	7	.....	+.15	Several wells about this depth.
Tulare (E. Jacob's Ranch).	....do	539	9	.....	+.1	Some gas.
Do[5]	....do	498	9	.....	+.1	Do.
Do[6]	....do	887	9	.....	+.35	Gas well.
Do	....do	835	9	.....	+.3	
Tulare (city wells) ..	....do	552	9	Many.	−15	Several wells.
Tulare	....do	720	8	300	Flows.	Several wells about this depth.
Tulare (about 20 miles southwest; Lambertson Ranch).[7]	....do	1,058	9	Many.	+.75	Gas at 600 and 700 feet.
Tulare (7 miles west)[8]	....do	730	8	.....	+.35	
Vinton	Plumas	700	.....	150	Flows.	
Visalia	Tulare	775	7	190	Flows.	
Watsonville	Santa Clara ..	540	.....	.....	−2	
Waukena	Tulare	450-816	8-9	Many.	Flow.	Several wells.
Wheeler Canyon[9] ...	Ventura	400-900	.....	.....	.....	Do.
Wild Bill Gulch[10] ...	....do	850-975	.....	.....	.....	Oil wells.
Winchester	Riverside	400	.....	.....	.....	
Yreka	Siskiyou	700	4¼	135	+32	

[1] Record, Cal. State Mining Bureau, Bull. No. 3, Gas and Petroleum Formations of the Central Valley of California, p. 18.
[2] Record, ibid., pp. 15-16.
[3] Cal. State Mining Bureau, 12th Rept., 1893-94, pp. 353-354; Record, Cal. State Mining Bureau, Bull. No. 3, Gas and Petroleum Yielding Formations of the Central Valley of Cal., p. 30.
[4] Cal. State Mining Bureau, Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, p. 27.
[5] Cal. State Mining Bureau, 11th Rept., 1891-92, p. 489.
[6] Ibid., pp. 488-489.
[7] Ibid., p. 488.
[8] Ibid., p. 487.
[9] Cal. State Mining Bureau, Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, p. 37.
[10] Ibid., p. 36.

PUBLICATIONS RELATING TO DEEP BORINGS IN CALIFORNIA.

California State Mining Bureau, Seventh Annual Report of the State Mineralogist for the year ending October 1, 1887, 315 pages, Sacramento, 1888.

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California State Mining Bureau, Eleventh Report of the State Mineralogist (first biennial), two years ending September 15, 1892, 612 pages, Sacramento, 1893.

California State Mining Bureau, Twelfth Report of the State Mineralogist (second biennial), two years ending September 15, 1894, 541 pages, Sacramento, 1894.

California State Mining Bureau, Bulletin No. 3, the Gas and Petroleum Yielding Formations of the Central Valley of California, by W. L. Watts, 99 pages, plates and maps, Sacramento, 1894.

California State Mining Bureau, Bulletin No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, by W. L. Watts, 94 pages, plates, map, Sacramento, 1897.

COLORADO.

Location.		Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Town.	County.					
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Acequia	Douglas	442		15	Flows.	
Do	do	598		4	Flows.	
Akron	Washington	1,260				Failure; abandoned.
Alamosa	Conejos	505	3	3	Flows.	
Do	do	604	3	225	Flows.	
Do.[1]	do	856	6–8	1,000	Flows.	Temp., 65°.
Do	do	465	3¼	Many.	Flows.	
Do	do	474	2	Many.	Flows.	
Do	do	1,000	7¼–6	Many.	Flows.	Temp., 75°.
Do	do	900	8	Many.	Flows.	2 wells; temp., 70°.
Arvada	Jefferson	460			Flows.	
Artesian	Arapahoe	700		Very few.	Flows.	
Do	do	565		20	Flows.	
Do	do	720		10	+ 35	
Boulder	Boulder	400	2	5	Flows.	
Do	do	+1,000			+ 20	Water too "alkaline."
Boulder (4 miles east)	do	600				Unsuccessful.
Bonita	Arapahoe	725	3	80	Flows.	
Brighton	do	408	3	30	+ 15	
Do	do	700		Few.	Flows.	
Do	do	500				
Burlington	Kit Carson	600		Small.	Flows.	
Byers	Arapahoe	450	2	1¼		
Calhan[2]	El Paso	566	6			Saline water.
Canon City	Fremont	1,000		700	+100	Temp., 90°.
Canon City (near)	do	1,278	4¼	⅛	— 15	Water at 350 feet.
Cheyenne Wells[3]	Cheyenne	1,770				For water. Abandoned.
Do	do	1,702				For gas. Failure.
Colfax	Custer	627		7	Flows.	
Colorado City	El Paso	2,020				Gas. Pressure 155 pounds to square inch. Now filled with surface water.
Do	do	1,300				Gas at 216 feet. Shut off by water. (Blue shale below 35 feet.)
Colorado Springs	do	1,120				
Cotton Creek	Saguache	405	3	75	Flows.	Temp., 58°.
Cortez[4]	Montezuma	795		Several	No flow.	
Crestone	Saguache	426	3	10	Flows.	
Do	do	446	3	75	Flows.	
Del Norte	Rio Grande	607			Flows.	
Delta	Delta	575	2¼	Few.	Flows.	
Do	do	580	3		Flows.	
Denver[5]	Arapahoe	350	2¼	½	+ 6	Temp., 56°.
Do	do	407	3–2	30	+ 25	Temp., 62°.
Do	do	444		50		
Do	do	500	3	40	+ 60	Temp., 50°.

[1] Record, 51st Congress, 1st session, Senate Ex. Doc., No. 222, p. 223, Washington, 1890.
[2] Record, 51st Congress, 1st Session, Senate Ex. Doc., No 222, p. 216, Washington, 1890.
[3] Record, U. S. Geol. Surv., 16th Ann. Rep., 1894–95, Part II, p. 563, Washington, 1895.
[4] Record, Colorado State Engineer, 8th Annual Report for 1895–96, pp. 69–70.
[5] In Denver and vicinity there are several hundred wells, mainly from 350 to 1,000 feet deep. They yield flows of considerable size from several horizons, but owing to large number of wells the volume of water is now greatly decreased. The wells are described in the following publications: 51st Congress, 1st session, Senate Ex. Doc. No. 222, pp. 175–205, 227–228, Washington, 1890; Monograph, U. S. Geol. Surv., Vol. XXVII, Geology of the Denver Basin, by S. F. Emmons, W. Cross, and G. H. Eldridge, 4°, Washington, 1896.

COLORADO—Continued.

Location.		Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Town.	County.					
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Denver	Arapahoe	575	9–6¼	Small.	No flow.	
Do	do	604	3–4			
Do	do	625	4	60	+ 60	
Do	do	720	3¼	10	+ 35	
Do	do	725	3	70	+ 40	
Do	do	810	4	70	− 5	Flow pumped down.
Do	do	856	3¼–2¼	10	+ 20	
Do	do	908	2¼		− 24	
Do	do	1,069	5			
Do	do	1,103			No flow.	
Do	do	1,250				Drilled for oil. Salt water to —40. Well abandoned.
Durango	La Plata	400			Flows.	
Eaton	Weld	970			No flow.	Much water at 230–260 feet. Some water at 400 and 625 feet.
Evans	do	1,200		Few.	Flows.	Water from 1,125 ft.
Fleming	Logan	423			—160	Very small supply of water.
Florence[1]	Fremont	780		1	Flows.	Numerous oil wells in vicinity.
Do	do	+1,000		700	Flows.	Water at 1,000 feet.
Do	do	+ 800		1,000	Flows.	Temp., 86°.
Fort Logan	Arapahoe	685			No flow.	
Do	do	558	4		No flow.	
Fort Lupton	Weld	904			− 4	
Fort Lyon	Bent	815				Abandoned. Small amount of water at 430 feet.
Franceville Junction	El Paso	Many.				
Georgetown	Clear Creek	658	2	120	100	
Grand Junction	Mesa	1,000	6¼–5¼	Few.	No flow.	Some gas at 444, 700, and 864 feet.
Greeley[2]	Weld	446	2¼	¼	No flow.	
Do	do	970	4		− 20	
Do	do	1,165		40	Flowed at first.	Several wells.
Do	do.[3]	2,140	8–4	Few.	− 40	Water from 1,165–1,200 feet.
Hoehne	Las Animas	936				Well abandoned.
Hygiene[4]	Boulder	965				Flowed at 675 feet.
Irondale	Arapahoe	500	6–4	60	Flows.	
Iron Springs	Otero	1,006			—556	Flows at 240 and 375 feet; unsatisfactory water at 1,006 feet. In progress.
Island Station	Arapahoe	440	8	60	Flows.	
Do[5]	do	430	4	15	+ 40	
Do	de	730			—125	
Kit Carson	Cheyenne	1,460				No fresh water; salt water at 450 feet.
Lajunta[6]	Otero	412	4¼	8	Flows.	Temp., 68°.
Do	do	420	8–6	45	Flows.	2 wells; temp., 70°.
Do	do	439	6			Temp., 68°.
Do	do	640	5¼	35	Flows.	Temp., 68°.
Do	do	670	8¼	15	Flows.	
Do	do	700	6			Do.
Do	do	740	7¼	12½	Flows.	Temp., 75°.
Do	do	766	7¼	25		Temp., 68°.
Do	do	1,152	5¼	Many.	Flows.	
Lamar[7]	Prowers	560	5¼	5	Flows.	Can pump 80 gals.
Lamar (northwest of).	do	420			No flow.	
Langford (4 miles northeast).	Boulder	400	2	3	Flows.	
Larkspur	Douglas	560				
Las Animas	Bent	+500		82		
Las Animas (7 miles northeast).	do					See Fort Lyon.

[1] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 214, Washington, 1890.
[2] Fifty-first Congress, 1st session, Senate Ex. Doc. No. 222, pp. 209–210, Washington, 1890.
[3] Analysis, ibid., p. 226.
[4] Record, ibid., p. 208.
[5] Fifty-first Congress, 1st session, Senate Ex. Doc. No. 222, p. 197, Washington, 1890.
[6] Record, Colorado State Engineer, Ninth Biennial Report, for 1897–98, pp. 28–29.
[7] Record, Colorado State Engineer, Ninth Biennial Report for 1897–98, p. 29; analysis, 51st Congress, 1st session, Ex. Doc. No. 222, p. 228, Washington, 1890.

COLORADO—Continued.

Location. Town.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Leadville	Lake	400		30		
Littleton	Arapahoe	467	3¼	20		2 other similar wells, 440 and 480 feet.
Do	do	500	3¼-2¼	16		
Do	do	510		25	+ 35	
Do	do	525		9	Flow.	Temp., 62°. Several similar wells from 520 to 560 feet deep.
Do	do	580		8	Flow.	
Do	do	601		15	+ 16	Several similar wells from 600 to 675 feet deep.
Do	do	710		45		Several similar wells from 700 to 735 feet deep.
Do	do	810		+1		
Do	do	1,300	8-4	3¼	+ 50	
Lockett	Saguache	418	3		+ 11	
Longmont	Boulder	431	4	+2		
Do	do	506			No flow.	
Do	do	600	6	40	+ 30	
Do	do	640	3¼	Few.		
Loveland[1]	Laramie	2,465		1	Flowed.	Water at 1,365 feet.
Lyman	Arapahoe	620		10		
Manzanola	Otero	1,113	5¼	42	Flows.	Temp., 80°.
Moffat	Saguache	404	3	Few.	Flows.	
Do	do	650			Flows.	
Do	do	710	2		+ 1¼	
Montrose	Montrose	825		30	Flow.	Temp., 72°.
Mosca	Costilla	610	4¼		+ 3	
Do	do	420	4		Flow.	
Ordway	Otero	1,575	4¼	Many.	—250	Temp., 63°.
Otis[2]	Washington	2,400		None.		Abandoned.
Petersburg	Arapahoe	600		20	+ 35	
Do.[3]	do	720	3¼-2¼	10	+ 35	
Pueblo[4]	Pueblo	772	4¼	2¼	Flows.	
Do	do	782		3-5	Flows.	
Do	do	789	5¼	300	Flows.	
Do	do	1,150		3	Flows.	
Do	do	1,219	4¼	20	+125	Temp., 76°.
Do	do	1,260		20–25	Flows.	
Do	do	1,400	3	¾	+140	Temp., 77°.
Do	do	1,402		+ 87	+140	
Rocky Ford	Otero	767	5¼	130	Flows.	Temp., 78°.
Do	do	790	10-4¼	68	+ 75	Temp., 74°.
Do	do	793	7¼	68	Flows.	Temp., 78°.
Do	do	820	7¼	38	Flows.	Temp., 75°.
Do.[5]	do	845	4	115	Flows.	Temp., 72°.
Do	do	1,033	6	17	Flows.	Temp., 75°.
Rouse Junction	Huerfano	2,058		Few.	—200	Salt water at 890 feet, small amounts of water at 700 and 1,600 feet.
Saguache	Saguache	400	4¼			
Salt Creek	Pueblo	2,030			No flow.	Small amount of water at various depths. Abandoned.
Scranton[6]	Arapahoe	800±	3			Coal prospect. No water.
Sedalia	Douglas	650	2¼			
Do	do	710			No flow.	
Do	do	1,440				Water from 200 to 300 feet only.
Sedalia (5 miles south.)[6]	do					
Sheridan	Arapahoe	580		20		
Do	do	620		10		
Sheridan Lake	Kiowa	1,280	6		—280	Water at 1,200 feet. Abandoned.
Stout[7]	Larimer	1,225		1	+ 30	Poor water 922-1,000 feet.

[1] Record, 51st Congress, 1st session; Senate Ex. Doc. No. 222, pp. 210-211, Washington, 1890.
[2] Ibid., p. 217, Washington, 1890.
[3] Ibid., p. 204.
[4] Records, etc., ibid., pp. 213-214; analyses, ibid., p. 229.
[5] Record, Colorado, State Engineer 9th Biennial Report, 1897-1898, p. 29.
[6] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 207, Washington, 1890.
[7] Ibid., p. 211.

COLORADO—Continued.

Location.		Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Town.	County.					
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Thatcher	Las Animas	936	5¼			
Timpas	Otero	795	6¼	35	Flows.	
Troy	Las Animas	400 or 500				
Trinidad	do					
Do	do	2,595	5¼	Many.	−195	
Walsenburg	Huerfano	1,250				For gas, entirely in shale. Salt water at −40 feet.
Westcliffe	Custer	500		None.		Abandoned.
Whiteriver	Rio Blanco	402				Salt water at 200 feet.
Do	do	506¼				Much gas at 500 feet.
Wray	Yuma	+500				For oil or coal; unsuccessful.

PUBLICATIONS RELATING TO DEEP BORINGS IN COLORADO.

Report of L. G. Carpenter, Field Agent for Colorado, Fifty-first Congress, first session, Senate Ex. Doc. No. 222, pp. 173–232, Washington, 1890.

Report of P. H. Van Diest, on the Geological Conditions of Artesian Basins in Eastern Colorado and New Mexico, Fifty-first Congress, first session, Senate Ex. Doc. No. 222, pp. 87–97, Washington, 1890.

Artesian Wells of Colorado and their relation to irrigation. State Agricultural College, Bulletin No. 16, July, 1891, 28 pages.

Economic Geology, by George H. Eldridge, Geology of the Denver Basin in Colorado, United States Geological Survey, Monograph No. 27, pp. 317–465, Washington, 1896.

Underground Waters of the Arkansas Valley in Eastern Colorado, by G. K. Gilbert, United States Geological Survey, 17th Annual Report, 1895–1896, part 2, pp. 1–51, plates, Washington, 1896.

United States Geological Survey, Geologic Atlas of the United States, No. 36, Pueblo folio, by G. K. Gilbert, Washington, 1897.

United States Geological Survey, Geologic Atlas of the United States, No. 58, El Moro folio, by R. C. Hills, Washington, 1899.

United States Geological Survey, Geologic Atlas of the United States, No. 68, Walsenburg folio, by R. C. Hills, Washington, 1899.

CONNECTICUT.

Location.		Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Town.	County.					
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Bridgeport	Fairfield	800		Several	No flow.	
Mansfield	Tolland	800	6	14	No flow.	
Meriden	New Haven	530	12	70	No flow.	Water very hard.
New Haven	do	3,800				Unsuccessful.
Noroton	Fairfield	700		None.		
Do	do	1,500		4	No flow.	4 gallons at 900 feet.
Pomfret Center	Windham	610	6	Few.	No flow.	
Putnam Heights	do	800		Few.	No flow.	
Do	do	400	6	4	No flow.	
Do	do	700		7	No flow.	
Do	do	420		2	No flow.	
Rockville	Tolland	3,440		Not any		Abandoned.
Stamford	Fairfield	450	8			Water unsatisfactory.

DELAWARE.

Location.		Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Town.	County.					
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Bowers Beach [1]		500	3¼	200	No flow.	Not much water below 240 feet.
Delmar [2]	Sussex					
Lewes [3]	do	400	6	15	At surface.	
Do [4]		1,080		15	Flows.	
Middletown [5]	Newcastle	535	10–8	330	−50	Water also at 475 feet.
Do. [6]	do	698				Water from 535 and 660–686 feet.
Wilmington	do	400	8	15–18		
Do	do	1,077		10	−25	

DISTRICT OF COLUMBIA.

Washington, Heurich's old Brewery.		900		7		Abandoned.
Washington. Riggs House.		558		None.		Unsuccessful.

FLORIDA.

Apalachicola	Franklin	475	3¼			Temp., 68°.
Bartow (8 miles southwest).	Polk	600				Small vein of water at 300 feet.
Do	do	400				
Eau Gallie	Brevard	490	6		+ 48	Temp., 78°.
Fernandina [7]	Nassau	640	8	800	+ 50	Water from 618 feet.
Do	do	750	6		+ 64	Temp., 77°.
Fernandina (city park).	do	700	8	810	+ 40	Temp., 74°.
Fernandina	do	762				
Green Cove Springs	Clay	600	6	600	+ 30	Temp., 80°.
Heart's Road [8] (R. R. junction).	Nassau	750	6	Many.	+ 64	Temp., 77°.
Hobe Sound	Dade	1,100	4	Few.	Flows.	Sulphur water.
Jacksonville [9]	Duval	793	6		+ 17	
Do	do	711			Flows.	Do.
Do	do	630	6	432		Temp., 74° to 77°.
Do	do	660	6	[9] 950	+ 64	Do.
Do	do	1,020	10			Temp., 81°.
Do	do	937	12	432		Temp., 77°.
Do	do	490	3	180	+ 62	Temp., 75°.
Do	do	637	6	600	+ 62	Temp., 76°.
Do	do	650	6	900	+ 62	Do.
Do	do	1,020		2,333	+ 62	Temp., 78°.
Do	do		8–4			
Jasper	Hamilton	+550				In progress.
Key West	Monroe	2,350				
Kissimmee	Osceola	406	4			
Lake Worth [10]	Dade	1,212	4	313	+ 40	
Live Oak	Suwanee	1,004	8	Many.	− 80	Temp., 60°.
Madison	Madison	530	6	100	−117	
Malabar	Brevard	510	3	Many.	Flows.	Temp., 78°; bored for oil; none found.
Melbourne	Brevard	400	6		+ 48	Temp., 78°.
Narcoossee	Osceola	416	3		− 27	
Ocala	Marion	1,210	8		− 74	
Orchid	Brevard	480	4	Few.	Flows.	Sulphur water.
Pasadena	Pasco	450			− 86	
Pensacola	Escambia	1,400				Navy-yard well. No good water.

[1] New Jersey Geol Surv., Report for 1899, p. 110.
[2] Record, ibid., pp. 111-112.
[3] Record, U. S. Geol. Surv., Bull. 138, p. 124.
[4] Record, New Jersey Geol. Surv., Report for 1898, pp. 83–87.
[5] Record, U. S. Geol. Surv., Bull. No. 138, p. 123.
[6] Record, New Jersey Geol Surv., Report for 1898, p. 115.
[7] Georgia Geol. Surv., Bull. No. 7, pp. 75–76.
[8] Representative wells.
[9] Both wells.
[10] Record, etc., Am. Jour. Sci., 3d series, vol. 41, pp. 105–106.

FLORIDA—Continued.

Location. Town.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Punta Gorda	De Soto	467				Water too salty for use.
Do	do	400			Flows.	
Do	do	425		25	Flows.	Salt water only.
Quincy	Gadsden	610	6–4¼		−190	
Riverside	Putnam			Many.	Flow.	2 wells.
Roseland	Brevard	462–450	6	Many.	Flow.	2 wells.
St. Augustine [1]	St. John	1,400		5,500		Temp., 86°. Strong flows also at 400–450 and 500–550 feet.
St. Nicholas	Duval	750	6		+ 60	Temp., 77°.
South Jacksonville	do	800			+ 55	
Do	do	750	6		+ 69	Do.
Tallahassee	Leon	715			− 98	

GEORGIA.

Abbeville [2]	Wilcox	540	4		− 25	Water at 90, 139, and 296 feet.
Albany	Dougherty	665	2	20	Flows.	
Do. [3]	do	700–780	6–4	20–115	+ 24	Numerous wells. Temp., 73½°.
Do. [4]	do	732	10	225	+ 30	
Albany (16 miles west).	do	550				Pure water.
Americus	Sumter	1,725	8–4		− 30	Water at 1,000 feet.
Do	do	400			− 10	Supply is derived from the 350-foot level.
Do. [5]	do	500			− 10	
Do	do	900			Flows.	
Do	do	550	4	33	+ 1	
Arlington [6]	Calhoun	625	6		− 20	Water at 500, 600, and 700 feet. Hard and slightly chalybeate.
Augusta [7]	Richmond	814	8	18	−196	
Do. [8]	do	879	6			Five water-bearing strata penetrated.
Bainbridge [9]	Decatur	900	6–2		− 50	
Do. [10]	do	1,325				Water at 280 and 370 feet.
Do	do	965	6–2		− 59	
Barrington [11]	McIntosh	450	3	200	+ 20	Flows at 350 and 450 feet.
Baxley [12]	Appling	507	6		−129	Water at 320 and 408 feet.
Bladen [13]	Glynn	480	3	100	+ 30	Water at 160, 260, and 475 feet.
Bowen's Mills	Wilcox	673	2¼	60	+ 22	Temp., 74°.
Bradley's plantation [14].	Stewart	740	3		Flows.	Water from 475 feet.
Brunswick [15]	Glynn	450–490	3	200	+ 28	Numerous wells.
Do	do	415	3		+ 19	Temp., 62°.
Do	do	540	8	600	+ 12	
Do	do	430	4		+ 25	
Do	do	460	6	350	+ 12	
Do	do	465	4	600	Flows.	Temp., 70°.
Buena Vista [16]	Marion	583	10		−240	Water at 331 and 364 feet.
Camilla	Mitchell	600			No flow.	Nonflowing.
Chauncey [17]	Dodge	525	6		− 70	Water at about 300 ft.
Collins	Tatnall	800	8		−142	
Columbus, 3 miles south of.	Muscogee	425	3	2	− 4	Water at 400 feet.
Cookstown	Wilcox	+400			No flow.	3 wells reported.
Cordele [18]	Dooly	550	8		− 20	
Do	do	700	6		− 30	
Creytons Island [19]	McIntosh	414	3		+ 50	

[1] Am. Jour. Sci., 3d series, vol. 34, p. 70.
[2] Ga. Geol. Surv., Bull. No. 7, p. 151.
[3] Analysis and record, ibid., pp. 179–181.
[4] Record, ibid., pp. 178–179.
[5] Record and analysis, Ga. Geol. Surv., Bull. No. 7, pp. 174–176.
[6] Record, ibid., p. 185.
[7] Ga. Geol. Surv., Bull. No. 7, pp. 128–129.
[8] Ibid., p. 130.
[9] Analysis, ibid., pp. 160–161.
[10] Id., p. 162
[11] Ga. Geol. Surv., Bull., No. 7, p. 109.
[12] Ibid., p. 149.
[13] Ibid., pp. 92–93.
[14] Record, Ga. Geol. Surv., Bull. No. 7, p. 197.
[15] Ibid., p. 86.
[16] Ibid., p. 198.
[17] Ga. Geol. Surv., Bull. No. 7, p. 145.
[18] Record, Ga. Geol. Surv., Bull. No. 7, pp. 159–160.
[19] Ga. Geol. Surv., Bull. No. 7, p. 109.

GEORGIA—Continued.

Location.		Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Town.	County.					
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Cumberland Island [1]	Camden	600	4		+ 12	
Do. [2]	do	485	4		+ 12	
Do. [3]	do	680	6	555	+ 51	Water sulphurous.
Cuthbert	Randolph	1,000	6-4		− 30	Water also at 340-400 and 550 feet.
Damascus [4]	Early	547	2		− 7	Water also at 200 ft.
Darien	McIntosh	492	4			
Do. [5]	do	530	8	200	+ 15	
Dawson [6]	Terrell	650	5-2		− 45	
Doboy	McIntosh	450	6	250		
Drayton	Dooly	400	8	8	Flows.	Temp., 50°.
Dry Creek [7]	Burke	763	2		− 30	Water also at 280 and 375 feet.
Dublin	Laurens	850	8			First flow at 350 feet.
Duckers Station [8]	Dougherty	547	2		+ 10	
Eastman [9]	Dodge	680	4	Many.	−120	
Eastman	do	+600		Not any		Abandoned.
Do	do	720			−200	
Egypt [10]	Effingham	750	4		− 45	Water at 300 and 750 feet.
Evelyn	McIntosh	500	2		+ 45	Sulphurous water.
Do	Glynn	420	3		+ 14	Do.
Everett City	do	460	2		+ 38	
Everetts Station	Crawford	+400				
Fitzgerald [11]	Irwin	680	6-3		− 27	
Do	do	800	10		−150	
Do	do	1,000	6		−128	
Do	do	853	12-8	139	−320	
Florence, 3 miles west on Chattahoochee River.	Stewart	490	6	½	+ 20	
Do	do	490	2	½	+ 20	
Do	do	445		1½	+ 30	
Do	do	455		½	+ 20	
Fort Gaines	Clay	650	4-3	150	− 20	Water at 500 feet.
Do	do	800		400	− 12	
Fort Valley [12]	Houston	1,075	6-4		−100	
Do	do	500		Not any		Abandoned.
Do	do	1,200		Not any		
Hawkinsville [13]	Pulaski	490	6		Flow.	Temp., 71°.
Irwinville	Wilkinson	600	3		(?) + 50	
Jekyl Island [14]	Glynn	480	6	250	+ 45	
Jesup [15]	Wayne	500	2		− 33	Water also at 287 feet.
Kingsland	Camden	475	2	60	Flows.	
Do [16]	do	500	2	33½	+ 20	
Leary [17]	Calhoun	672	5-2	23	+ 30	
Leary, 3 miles north	do	400			No flow.	Abandoned.
Leesburg	Lee	500-600	8		No flow.	Temp., 68°. Mineral water.
Louisville [18]	Jefferson	450	4			Several wells. Those on low ground flow.
Lumber City [19]	Telfair	400	2	60	+ 14	6 wells. Water also at 300 feet.
Lyons [20]	Montgomery	400	3	10	− 84	Main water horizon at 375 feet.
McArthur [21]	do	900	3		− 60	Water at 419 and 890 feet.
Macon [22]	Bibb	955	12	Not any		Abandoned.
Manassas	Tatnall	498	6		−148	
Meldrim	Effingham	538	6	Many.	Flows.	
Milledgeville	Baldwin	600 or 700		Many.	No flow.	
Millen [23]	Screven	430-450	4-6		+19	Several wells.
Montezuma [24]	Macon	500		300	+62	2 wells.
Do	do	425		5	Flows.	Temp., 62°.
Do	do	425		2	Flows.	Do.

[1] Analysis, Ga. Geol. Surv., Bull. No. 7, pp. 78-79.
[2] Ibid., pp. 78-79.
[3] Record, ibid., pp. 76-77.
[4] Ga. Geol. Surv., Bull. No. 7, pp. 183-184.
[5] Record, ibid., pp. 105-108.
[6] Ibid., pp. 187-188.
[7] Ga. Geol. Surv., Bull. No. 7, p. 128.
[8] Record, ibid., p. 182.
[9] Analysis, ibid., pp. 144-145.
[10] Ga. Geol. Surv., Bull. No. 7, pp. 121-122.
[11] Ibid., p. 152.
[12] Record, Ga. Geol. Surv., Bull. No. 7, p. 192.
[13] Ibid., p. 140.
[14] Analysis, ibid., p. 94.
[15] Record, Ga. Geol. Surv., Bull. No. 7, pp. 103-104.
[16] Ga. Geol. Surv., Bull. No. 7, p. 79.
[17] Record, ibid., pp. 186-187.
[18] Ibid., p. 132.
[19] Ibid., p. 150; Analysis and record, U. S. Geol. Surv., Bull. No. 138, p. 224.
[20] Record, Ga. Geol. Surv., Bull. No. 7, p. 146.
[21] Ibid., p. 147.
[22] Ga. Geol. Surv., Bull. No. 7, p. 193.
[23] Ibid., pp. 123-124.
[24] Record, ibid., pp. 189-190.

GEORGIA—Continued.

Location.		Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Town.	County.					
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Montezuma	Macon	450	2	30	+ 26	Flows at 60, 150, and 350 feet.
Do	do	450	4		+ 26	
Oglethorpe	do	490	2	66		Temp., 62°.
Pelicalville		430	4	400		Temp., ±70°.
Quitman[1]	Brooks	500?	6		− 30	Water at 109 feet.
Reynolds[2]	Taylor	700	8–4	60	− 80	
Riceboro[3]	Liberty	440	3	150	+ 20	
Do[4]	do	430	4	100	+ 24	Soft water.
Richland	Stewart	420	6	25	−120	
St. Marys[5]	Camden	525	4	Many.	+ 50	Water at 300 and 500 feet.
St. Simons Island	Glynn	480	6–3	100–150		3 wells.
Do.[6]	do	438	6	250	+ 40	Water 350 and 435 feet.
Savannah	Chatham	±650			− 18	
Do	do	1,500	12	Many.	No flow	
Do	do	500	10			2 wells reported.
Do	do	402–470	6	Many.		5 wells of old waterworks.
Do.[7]	do	475–700	12	13 wells 4,861		City waterworks comprising 13 wells.
Savannah (6 miles south).	do	1,147	4		+ 31	
Savannah (12 miles west on Great Ogeechee River).	do	±659			Flows.	Temp., 72°.
Sebastopol	Burke	676	6		− 2	Water at 200, 345, and 500 feet.
Smithville[8]	Lee	900	2,1,4	Many.	+ 20	2 wells.
Statesboro	Bulloch	415	7–4	40	−100	
Do	do	(?) 600	4			
Swainsboro[9]	Emanuel	400	6	21	− 80	
Do	do	400	2	10	− 90	
Tarboro[10] (1½ miles northeast).	Camden	414	2	Many.	+ 50	
Tennille[11]	Washington	990	12–4	Many.	−190	Water at 426 and 830 feet.
Thomasville[12]	Thomas	1,900	5	Many.	−210	
Do	do	480	8	Many.	−210	
Union Island		475	4	150		
Valdosta[13]	Lowndes	522	8		−113	Temp. 70°. Water at 360, 450, and 515 feet.
Valona	McIntosh	455	3	120	+ 60	Temp., 70°.
Wadley[14]	Jefferson	445	6	Many.	+ 20	13 wells reported. Flow also at 330 feet.
Warwick[15]	Worth	497	8–2	1	− 5	Sulphur water.
Waycross[16]	Ware	700	12	750	− 60	2 wells, pure water.
Do	do	500	6	150		
Do	do	600	4		− 55	
Waynesboro[17]	Burke	992	6		+ 14	Water at 250, 300, and 900 feet.
Do	do	1,260	8		− 52	
Do	do	760			No flow	
Do	do	425			No flow	
Do	do	618	4		− 18	
Do	do	876	6			Abandoned.
Ways Station[18]	Bryan	460	3	200	+ 20	Water at 340 and 440 feet.
Do	do	484	6–2	Many.		
Whiteoak[19]	Camden	450	4	300	− 60	Water at 130 and 450 feet.
Wolf Island		500	2		+ 45	Sulphurous water.
Wright		785	6–3		− 80	
Wrightsville[20]	Johnson	672	8		− 60	Water at 430 and 672 feet.
Do	do	763	3		− 63	

[1] Record, Ga. Geol. Surv., Bull. No. 7, pp. 156–157.
[2] Ga. Geol. Surv., Bull. No. 7, p. 194.
[3] Ibid., pp. 110–111.
[4] Ibid., p. 110.
[5] Ga. Geol. Surv., Bull. No. 7, pp. 74–75.
[6] Ibid., pp. 87–92.
[7] Record, ibid., pp. 114–120.
[8] Ibid., pp. 176–177.
[9] Ga. Geol. Surv., Bull. No. 7, p. 43.
[10] Ibid., p. 83.
[11] Record, ibid., pp. 133–136.
[12] Ibid., pp. 158–159.
[13] Analysis, ibid., pp. 154–156.
[14] Record, Ga. Geol. Surv., Bull. No. 7, p. 131.
[15] Ga. Geol. Surv., Bull. No. 7, p. 164.
[16] Record and analysis, ibid., pp. 96–102.
[17] Record, ibid., pp. 125–126.
[18] Ga. Geol. Surv., Bull. No. 7, pp. 111–112.
[19] Ibid., p. 82.
[20] Ibid., pp. 137–138.

PUBLICATIONS RELATING TO DEEP BORINGS IN GEORGIA.

Preliminary report on the artesian well system of Georgia, by S. W. McCallie, Geological Survey of Georgia, Bulletin No. 7, 214 pages, plates, Atlanta, 1898.

Artesian prospects in the Atlantic Coastal Plain region, by N. H. Darton, United States Geological Survey, Bulletin No. 138, 232 pages, plates, Washington, 1896.

IDAHO.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Boise	Ada	450		270	+ 10	Temp., 80°. Deepest of several wells. Hot wells average 555 gallons per minute, and have a height of +30 feet. Temp., 170°.
Bliss	Lincoln	483	8			
Clift		450	8			
Idaho City	Boise	+400				Prospect well. Not in use.
Minidoka	Lincoln	425				
Oakley	Cassia	±400				
Owinza	Lincoln	400				

ILLINOIS.

Aledo[1]	Mercer	3,115		Many.	— 75	Water at 1,200 feet. Salty water from 2,300 to 2,620 and 3,071 feet.
Algonquin[2]	McHenry	2,527				Bad water. Abandoned.
Alton	Madison	890	6-4	35-40	Flows.	2 wells; mineral water.
Amboy[2]	Lee	2,000			+ 3	Temp., 55° to 60°. Water at 300, 1,100, and 1,700 feet.
Aurora[2]	Kane	663				
Do.[3]	do	1,388	8-6	350		
Do.[3]	do	2,270			+ 60	
Do.[3]	do	2,255			+ 60	
Austin[4]	Cook	1,205		Many.		
Barry[5]	Pike	2,510	6	100	- 35	
Beardstown[6]	Cass	1,070		17		Water, oil, and gas.
Belleville	St. Clair	503			— 80	
Belvidere[4]	Boone	1,950	8-4	400	— 6	
Do	do	1,932	8-6	200	— 6	
Benton	Franklin	780	5	3	— 12	
Bethalto	Madison	1,000	12	15	— 25	Saline water.
Bradford	Stark	2,454	8-6	Many.	—175	
Braidwood	Will	900	4		At surface.	Water from 655 feet.
Cairo	Alexander	700-750		556	+ 10	4 wells.
Do	do	1,025				No water below 750 feet.
Cambridge	Henry	1,329	9-6	74	—146	
Camppoint	Adams	1,006				
Canton[7]	Fulton	2,500	4	125	+ 31	Water from 2,050 feet.
Do.[7]	do	1,646¼	14-6	260	+ 15	Water from 1,100 to 1,305 feet and 1,403 to 1,646¼ feet.
Do.[8]	do	2,333				Unsuccessful.
Carbon Cliff[9]	Rock Island	915	5¼	400	+ 50	Brackish water at 850 feet.
Do.[7]	do	950				
Carmi	White	600		Many.	Flows.	
Carrollton[7]	Greene	1,330			— 50	Water from 1,225—1,330 feet.

[1] U. S. Geol Surv., 17th Ann. Rept., 1895-96, part 2, p. 810.
[2] Ibid., p. 810.
[3] Analysis, ibid. p. 820.
[4] U. S. Geol. Surv., 17th Ann. Rept., 1895-96, part 2, p. 810.
[5] Analysis, ibid., p. 827.
[6] Record, Ill. Geol. Surv., pp. 61, 66.
[7] Record, U. S. Geol. Surv., 17th Ann. Rept., 1895-96, part 2, p. 849.
[8] Record, Ill. Geol. Surv. Rept., vol. 8, pp. 82-83.
[9] Record, ibid., pp. 64-65.

ILLINOIS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Carthage[1]	Hancock	1,800	5–3		− 16	Brackish water at about 750 and 1,000 feet.
Do.[1]	do	1,000	10–8		− 20	Water at 865 and 975 feet.
Do.[2]	do	1,787			+ 5	Mineral water.
Do.[3]	do	975		Many.		Do.
Centralia[4]	Marion	864	6			Unsuccessful.
Champaign	Champaign	400				
Charleston	Coles	2,600				Salt water at 160 and 815 feet.
Do	do	748±				
Chatsworth[5]	Livingston	1,200			− 25	
Chicago[6]	Cook	694	5		− 13	Hard water, original head +77 feet.
Do.[7]	do	711	4¼	400	− 13	Original head +77 feet.
Do	do	1,400				Unsuccessful.
Do.[8]	do	1,200			At top.	Hard water.
Chicago (Union Stock Yards).[9]	do	1,105				
Chicago (Lehman Well).	do	2,604				Brackish water.
Chicago (Swift & Co.)	do	2,700				
Chicago (Stockton)	do	2,180 2,186		840	− 30	2 other wells.
Collinsville	Madison	573			−120	
Columbia	Monroe	1,010	5¼		− 10	Water not pleasant.
Coulterville	Randolph	1,117				Water brackish.
Do	do	1,201				No gas or oil found.
Danville Junction	Vermilion	2,008				Brackish water at 1,709 to 1,735 feet.
Decatur[9]	Macon	507				
Dekalb	Dekalb	800	8–6	Many.	− 25	
Do	do	880	10–8	Many.	− 55	
Do	do	890	14–6	300	− 65	Water 125 to 161 and 595 to 890 feet.
Do	do	981	6–4	Many.	− 60	
Do	do	700		Many.	− 40	
Denver (near)	Hancock	1,030		Many.	− 40	
Divernon	Sangamon	604		Not any		Coal prospect.
Dixon[10]	Lee	1,640 1,730 1,810		Many.		3 wells.
East Dubuque	Joe Daviess	940	5		− 95	
East Moline	Rock Island	1,340	6	240	+ 36	750 and 1030 to 1080 feet.
East Peoria	Tazewell	734				Brackish water at 317 and 734 feet.
East St. Louis	St. Clair	1,100				Good drinking water, but unfit for boilers.
Eldorado	Saline	520	3¼	Few.		
Elgin[11]	Kane	1,400				Water at 487 to 514 feet; sulphur water at 650 to 700 feet.
Do.[12]	do	1,876			+ 2	Also sulphur water at 650 to 700 feet.
Do.[13]	do	2,026	6		+ 27	Sulphur water at 650 to 700 feet; soft water at 2,024 feet.
Do.[13]	do	2,230			− 4	Also sulphur water at 650 to 700 feet.
Equality	Gallatin	1,800	6–3¼			Very salt water at 900 feet.

[1] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 810.
[2] Record, Ill. Geol. Surv. Rept., vol. 8, pp. 64–65.
[3] Record, ibid., p. 62.
[4] Record, Economic Geology of Ill., vol. 2, pp. 138–139.
[5] Record, Economic Geology Ill., vol. 3, pp. 595–596.
[6] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 811.
[7] Ibid., p. 811.
[8] Record, Economic Geology Ill., vol. 2, p. 186.
[9] Record, Economic Geology Ill., vol. 3, pp. 538–539.
[10] Analysis, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 827.
[11] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 812.
[12] Ibid., p. 812.
[13] Ibid., p. 812; Analysis, ibid., p. 827.

ILLINOIS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Evanston [1]	Cook	1,602			+ 5	Water at 562 to 832 feet.
Fairbury [2]	Livingston	571				Water at 427 feet.
Do	do	2,002	8		− 60	
Franklin	Morgan	1,200				Flow for gas unsuccessful.
Fulton [3]	Whiteside	1,246	5	300	+ 61	First flow, 475 feet; sulphur water.
Galena [4]	Jo Daviess	1,209	8	166	+ 85	
Galesburg [5]	Knox	1,236				City waterworks well No. 2.
Do. [6]	do	1,226	14–6	120	−102	Water at 1,060 to 1,226 feet.
Galva	Henry	1,470	9–6	50	−178	
Genesee [7]	do	2,250	6	190	− 31	
Gilman	Iroquois	1,746		150	− 7	
Greenup	Cumberland	640	2			Mineral water.
Hamilton	Hancock	680		36	+ 63	Sulphur water.
Harvard	McHenry	900	12–7	90	− 41	Hard water.
Harvey	Cook	1,300 2,075		250	− 10	2 wells.
Hawthorne	do	989				
Do	do	2,005				
Hennepin	Putnam	800	4	80	+ 50	Slightly saline water.
Henry	Marshall	1,355	3½	32		White sulphur water.
Highland Park [8]	Lake	2,200	8–5	150	+ 9	Water at 900, 1,300, and 1,700 to 2,200 feet; slightly saline and hard.
Hinsdale	Dupage	864				
Ipava [9]	Fulton	1,570	4	60		Also salty and sulphurous water at about 1,010 feet.
Jacksonville [10]	Morgan	1,600				For gas.
Do. [11]	do	2,343	6–4½	30	− 15	Water brackish at 2,340 feet.
Do. [12]	do	2,408	5½	85	+ 10	Water brackish at about 2,100 feet.
Do. [12]	do	3,028	6½–5½	500	− 30	Water from 1,800 and 3,000 feet; slightly saline.
Jerseyville [13]	Jersey	2,003	12 3	200	100	Water at 1,400 to 1,600 feet.
Joliet [14]	Will	477		Many.	Flows.	
Do	do	1,200		500		
Do. [15]	do	1,700			+ 10	
Do. [16]	do	2,076			+ 10	
Kankakee [17]	Kankakee	1,000	4		− 15	Water from 900 feet.
Kewanee [18]	Henry	1,480	9–6	130	150	Water from 1,000 feet.
Do. [18]	do	1,050	7–4	80		2 wells.
Knoxville [19]	Knox	1,350	8	80		Water from 1,180 to 1,350 feet.
Ladd [20]	Bureau	400		135	Flows.	Shaft for coal. Flowed 3 gallons at 28 feet, 200 gallons at 173 feet, then decreased to 135 gallons.

[1] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 813; Analysis, Ibid., p. 827.
[2] Ill. Geol. Surv., vol. 6, p. 242.
[3] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 813.
[4] Ibid., p. 813; Analysis, p. 827.
[5] Analysis, Am. Inst. Mining Engineers, Trans., vol. 27, p. 135.
[6] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 813.
[7] Ibid., p. 813; Analysis, p. 827.
[8] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 813.
[9] Ibid., p. 813.
[10] Ill. Geol. Surv., vol. 8, p. 67.
[11] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 814; Analysis, Ibid., p. 820.
[12] Ibid., p. 814; Analysis, ibid., p. 820.
[13] Ibid., p. 814; Analysis, pp. 808, 827.
[14] Record, Economic Geol. Ill., vol. 2, pp. 482, 487.
[15] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 814; Analysis, Ibid., p. 821.
[16] Record, Ibid., pp. 799, 814.
[17] Ibid., p. 814; Analysis, ibid., p. 821.
[18] Ibid., p. 814; ibid., p. 821.
[19] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 814.
[20] Columbia College, School of Mines Quarterly, vol. 16, pp. 238–243.

ILLINOIS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Lagrange	Cook	2,014			No flow.	
Lake Forest [1]	Lake	960		60	+ 50	
Lancaster [2]	Wabash	+800	6			For oil; unsuccessful.
Lasalle [3]	Lasalle	502	6	200		
Lemont	Cook	1,396			+ 60	
Litchfield [4]	Montgomery	982				Oil with salt water and gas.
McLeansboro	Hamilton	800	8–5½	3½		
Macomb	McDonough	1,350			— 55	
Do. [4]	do	1,630				Water from 1,135 to 1,300 feet.
Marion	Williamson	1,715			Flow.	For gas and oil. Sulphurous and salt water found.
Marissa	St. Clair	685		35	No flow.	
Marseilles [5]	Lasalle	2,189		1	Flow.	Flow is from 298 feet.
Marshall	Clark	500				2 unsuccessful oil borings.
Mattoon	Coles	1,647	8	Many.		Salt water at 308 feet, and very salty at 1,500 feet.
Mendon	Adams	1,020				
Mendota [6]	Lasalle	400			— 47	
Do. [7]	do	857			+ 14	Flows at 187 and 637 feet.
Milan [8]	Rock Island	1,217				
Do. [9]	do	1,157	8–5	318	+ 61	Water from 800 and 1,000 feet.
Millstadt	St. Clair	620	7¼	4	— 75	Hard water.
Minonk	Woodford	1,755		100	—149	Moderately hard water at 750 feet and at about 1,700 feet.
Minorka	Gundy	2,100			+ 46	
Moline [10]	Rock Island	1,166		250	+ 25	
Do. [11]	do	1,628	5	350	+ 82	Sulphur water at about 700 feet.
Monmouth [12]	Warren	1,232				No flow water; no gas; no oil.
Do	do	1,400	6–4	210	— 60	
Do. [13]	do	1,230		200	— 60	Water from 1,074 to 1,230 feet.
Do. [14]	do	1,227			— 60	Water at 935 and from 1,074 to 1,227 feet.
Monticello	Piatt	1,100				Flow of mineral water also.
Morgan Park	Cook	1,046			45	Water at 1,040 feet.
Morris [15]	Grundy	408	10	Many.	Flows.	
Do	do	600				
Mount Carmel [16]	Wabash	700				Bored for oil.
Mount Carroll	Carroll	2,542	5			Much water at 1,200 feet; less from 1,300 to 2,500 feet.
Murphysboro	Jackson	500	8			Good water at 400 feet; saline water at 450 feet.
Oakpark	Cook	1,568	6¼	500	20	Water from 1,529 feet.
Do	do	2,200			—20	Water from 1,000 and 2,200 feet.
Olney [17]	Richland	2,000			No flow.	Saline water.

[1] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 814.
[2] Record, Economic Geol. Ill., vol. 3, pp. 58–60.
[3] Record Ill. Geol. Surv., vol. 7, p. 37.
[4] Analysis, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, pp. 808, 827.
[5] Record, Ill. Geol. Surv., vol. 8, p. 50.
[6] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 815.
[7] Record, Minnesota Geol. Surv., 13th Ann. Rept., pp. 55, 56.
[8] U. S. Geol. Surv., 17th Ann Rept., 1895–96, part 2, p. 846.
[9] Ibid., p. 815; Analysis, ibid., pp. 808, 827.
[10] Record, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, pp. 847, 848.
[11] Record, ibid., p. 848; Analysis, ibid., pp. 808, 827.
[12] Record, Ill. Geol. Surv. Reports, vol. 8, pp. 62–66.
[13] Record, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 848; Analysis, ibid., pp. 808, 827.
[14] Record, ibid., p. 848; Analysis, ibid., pp. 808, 827.
[15] Record, Economic Geol. Ill., vol. 2, p. 457.
[16] Record in part, Economic Geol. Ill., vol. 3, pp. 386–387.
[17] Ill. Geol. Surv. Reports, vol. 7, p. 8.

ILLINOIS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Ottawa[1]	Lasalle	400				Has 200 wells 400 feet deep. Water from 200 to 400 feet.
Do.[2]	do	1,840			+177	Water from 1,640 to 1,840 feet.
Palatin[3]	Cook	1,656			+2	Water at 160 and 800 feet.
Pana	Christian	2,507		Few.		Brackish water.
Paris	Edgar	2,200	8	Not any		
Park Ridge	Cook	1,500	6–3		−10	
Paxton	Ford	2,100 or 2,600.		Many.		
Pedicord	Lasalle	2,189		8	At surface.	Water from Potsdam 1,845 to 2,143 feet.
Pekin	Tazewell	850				Salt at 500 feet.
Do	do	1,000	6	167	+65	Salt water at 425 feet. Lower water strongly sulphurous. Temp., 70°.
Peoria (opposite)[4]	Peoria	734			+60	Sulphur water.
Peru[5]	Lasalle	1,360		200	+120	Water at 750 feet also.
Polo	Ogle	2,098		Many.		
Potsdam		1,500		Many.		
Princeton[6]	Bureau	2,500			−72	
Do	do	2,092	9¼–4¼	320		Water hard, slightly saline from 1,521 to 1,670 feet and 1,850 to 1,975 feet.
Do[7]	do	400				
Quincy	Adams	550–1,000				5 wells.
Ramsey	Fayette	+400				
Redbud	Randolph	580	3	4	+ 7	
Do	do	1,350	4		−20	
Review		1,400	6			Temp., 62°.
Do		1,233		208	54	Salt water from 600 to 1,008 feet.
Riverside[8]	Hancock	680		35	+63	Mineral water.
Do	do	1,300 2,200	3	1,000	+20	
Riverton[9]	Sangamon	2,584				No gas, oil, or water found.
Rock Island[10]	Rock Island	1,150	4	400	+70	Sulphur water at 750 and 980 feet.
Do.[11]	do	2,282	8–4¼		+50	Also sulphur water at 800 feet.
Rockford[12]	Winnebago	1,300-1,996	8–6	116–260	+ 8	Five wells. Water from 380 to 400 feet and 1,200 to 1,300 feet.
Do.[13]	do	400	6		− 8	
Rushville	Schuyler	2,500				Water has unpleasant taste.
St. Johns[14]	Perry	1,050		6		6 salt wells; brine at 970 feet.
Do	do	3,750				
Savannah	Carroll	1,432		500	+83	
Seneca	Lasalle	600–650				2 wells.
Do.[15]	do	680	4		+15	Water, which is hard and sulphurous, is from 350 and 380 feet.
Shelbyville	Shelby	1,200	6		Flows.	Water is saline, and from 625 feet.

[1] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 816.
[2] Record, ibid., pp. 798–799.
[3] Ibid., p. 816.
[4] Economic Geol. of Ill., Vol. 2, p. 449.
[5] Analysis, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 828.
[6] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 816; Analysis, ibid., pp. 808, 828.
[7] Record, Economic Geol. of Ill., vol. 3, p. 178.
[8] Record, Ill. Geol. Surv., vol. 8, pp. 64–65.
[9] Ill. Geol. Surv. Reports, vol. 8, p. 62.
[10] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 816; Analysis, pp. 808, 828; Record, pp. 845–846.
[11] Ibid., pp. 817, 845.
[12] Ibid., p. 816; Analysis, p. 828.
[13] Analysis, ibid., p. 828.
[14] Ill. Geol. Surv., vol. 7, p. 38.
[15] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 817.

ILLINOIS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Sheldon	Iroquis	1,800	10–5	100	−40	
Shawneetown[1]	Gallatin	1,513				For oil, only salt water found.
Do.[2]	do	1,500				At 500 feet, small vein gas; at 1,500, large quantity salt water.
Sparta[1]	Randolph	480			−75	
Springfield[3]	Sangamon	Nearly 1,200.			No flow.	
Sterling[4]	Whiteside	1,450		350	At surface.	
Streator[5]	Lasalle	2,496			+45	Water at 450, 2,170 to 2,496 feet.
Tuscola	Douglas	792				
Do	do	3,000	9–6			Temp., 60°.
Vermilion[6]	Lasalle	1,000		Many.	Flows.	Flows begin at 380 feet; water slightly saline.
Virginia	Cass	750				Water at 730 and 750 feet; unfit for drinking.
Washington Heights	Tazewell	1,308				
Warsaw	Hancock	780–800	4	100	+ 65	3 wells; water sulphurous.
Do	do	750	6	90	+155	Do.
Do	do	860	6	200	+ 62	Original head +98.
Waterloo	Monroe	1,096	9–7	20		20-gallon flow at 80 feet also. Temp., 50°.
Waukegan	Lake	1,135 1,600 2,005				Irony water; 3 wells.
Wenona	Marshall	1,854		100	− 25	
West Frankfort	Franklin	465				Coal prospect.
Wilmington[7]	Will	635	4		46	Sulphurous and magnesia water from 400 to 635 feet.
Winchester	Scott	412			+ 25	Water from 350 feet.
Winnetka[8]	Cook	1,570		150	+ 8	Original head, +18 feet.
Do	do	1,900				
Woodstock	McHenry	1,014		500		
Do	do	410	5		−130	

[1] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 817.
[2] Ky. Geol. Surv. Rept. Petroleum, Natural Gas, etc., by E. Orton, p. 205.
[3] Ill. Geol. Surv. Reports, vol. 5, p. 312.
[4] Analysis, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 828.
[5] Ill. Geol. Surv., vol. 7, pp. 50, 59; Record, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 798; Analysis Ibid., p. 821.
[6] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 818; Economic Geol. Illinois, vol. 2, p. 235.
[7] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 818.
[8] Analysis, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 828.

PRINCIPAL PUBLICATIONS RELATING TO DEEP BORINGS IN ILLINOIS.

Illinois Geological Survey, Reports on Geology and Palæontology, volumes 5, 1873; 6, 1875; 7, 1883, and 8, 1890.

Economical Geology of Illinois, by State geologist, volumes 2 and 3, Springfield, 1882.

The Water Resources of Illinois, by Frank Leverett, United States Geological Survey, Seventeenth Annual Report, 1895–96, part 2, pp. 695–849, plates, Washington, 1896.

INDIANA.

The numerous deep borings in Indiana are for oil or gas, but a few of them yield water supplies. The wells are in groups or "districts," often many square miles in extent. Where localities given in the following list are in districts, only representative wells are described, for it would not be practicable here to list all the individual wells. In some localities new wells are constantly being sunk.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Adams	Decatur	± 800				Gas well.
Alexandria	Madison	881				Gas wells.
Amboy [1]	Miami	940				Salt water at 385 feet.
Albany [2]	Delaware	978				Gas well.
Albion [3]	Noble	1,914				For gas; unsuccessful.
Anderson [4]	Madison	800				Water, mineral; city supply in part.
Do. [5]	do	800-900	8		−25	Gas wells in vicinity.
Arcadia [6]	Hamilton	974				Gas well.
Atlanta	do					Do.
Attica	Fountain	900			Flows.	Sulphurous water.
Auburn	Dekalb	+1,933				Gas wells.
Aurora [7]	Dearborn	1,000				Brackish water at 195 feet, brine at 831 feet, and gas at 967 feet.
Bloomington [8]	Monroe	2,730				No good water; abandoned.
Bluffton	Wells	100-500				Hard water.
Do. [9]	do	1,200				For gas; unsuccessful; salt water.
Boone Landing	Floyd					Gas wells.
Boonville	Warrick	1,400			No flow.	Gas well.
Boonville (4 miles west).	do	1,500	10 or 12		No flow.	
Boonville	do	1,200	12		Flows.	Salt water.
Bridgeport [10]	Marion	1,200				Gas well.
Brightwood	Marion	455			− 15	Several wells.
Do	do	476	8	139	- 60	Railroad well.
Do	do	1,181				Some gas, oil, and salt water.
Broad Ripple	do	+ 950				Gas wells.
Brookville (4 miles south). [11]	Franklin	1,254				Do.
Brownstown [12]	Jackson	1,891			−291	Flow of magnesia water at 565 feet; salt water at 1,891 feet.
Bryant	Jay	1,050				Oil well; abandoned.
Bunker Hill [13]	Miami	+1,004			− 20	For gas; unsuccessful; salt water.
Butler	Dekalb	600				Hard water.
Do [14]	do	2,139				For gas, unsuccessful; salt water.
Cadiz	Henry					Gas wells.
Cambridge	Wayne	+ 886				For gas; unsuccessful.
Camden	Jay					Gas wells.
Cannelton	Perry	750	8-5½		−150	Water and oil.
Carbon (2 miles south).	Clay	936				Not successful.
Do	do	1,255	10		− 40	Good water at 350 feet.
Carmel	Hamilton					Gas well; small product.

[1] Record, Ind. Geol. and Nat. Hist. Surv., 16th Rept., 1888, pp. 186, 187.
[2] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, p. 715.
[3] Ibid., p. 737.
[4] U. S. Geol. Surv., 18th Ann. Rept., 1896-97, part 4, p. 487.
[5] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, pp. 711-713.
[6] Ibid., p. 699.
[7] Ibid., p. 705.
[8] Record, Ind. Geol. and Nat. Hist. Surv., 15th Rept., 1885-86, p. 332.
[9] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, p. 740.
[10] Ibid., p. 701.
[11] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, p. 707.
[12] Ibid., p. 726.
[13] Ind. Geol. and Nat. Hist. Sem., 16th Ann. Rept., 1888, p. 186.
[14] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, p. 738.

INDIANA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Carthage[1]	Rush					Gas near 1,257 feet.
Centerville	Wayne	+ 886				For gas; unsuccessful.
Chandler	Warrick	1,505				2 flows of salt water and some gas.
Charlottesville	Hancock					Gas well.
Chesterfield[2]	Madison	948				Do.
Cicero	Hamilton					Gas well.
Circleville	Tipton	+1,078				For gas; unsuccessful.
Columbia City[3]	Whitley	1,375			— 20	For gas; unsuccessful. Salt water.
Columbus[4]	Bartholomew	1,700				Gas well.
Como	Jay					Do.
Connersville[5]	Fayette	851	8			Do.
Converse	Miami	200–435				Hard water; brackish water at 435 feet.
Do.[6]	do	900–950				Gas wells in vicinity.
Corydon	Harrison[7]	1,200				Gas boring.
	do	423–728	8–5½			Fresh water 30–130 feet; also salt water in lower strata.
Covington (3 miles below).	Fountain	1,000				
Cowan	Delaware	+ 935				Gas well.
Crawfordsville[8]	Montgomery	1,544				For gas; unsuccessful. Sulphur water at 750 feet.
Crown Point[9]	Lake	1,365			—120	For gas; unsuccessful. Salt water.
Do.[10]	do	3,300				Not successful.
Cumberland	Marion	+1,039				Salt water.
Daleville	Delaware	+ 870				Gas well.
Dalton	Wayne	+ 960				For gas; unsuccessful.
Danville	Hendricks	830				Abandoned.
Do	do	1,500	8–5	30		First water at 700 feet.
Decatur[11]	Adams	1,300				For gas; unsuccessful. Salt water.
Deer Creek (one-half mile south).	Carroll	± 840	6–4			Oil at 825 feet; salt or mineral water at 833 feet.
Delphi[12]	do	914				For gas; unsuccessful.
Do	do	1,200				
Delphi (2 miles southwest).[13]	do	923	6–4			Salt or mineral water at 923 feet.
Delphi (northeast)	do	928	6–4			Salt or mineral water at 928 feet; also oil.
Delphi (southeast, at water tower).	do	947	6–4		Flows.	Salt or mineral water at 922 feet; also oil and gas.
Delphi (southeast)	do	1,315	6–4		Flows.	Salt or mineral water at 898 feet; also oil and gas.
Delphi (northwest)	do	1,385	6–4			Salt or mineral water at 923 feet.
Desoto	Delaware					Gas well.
Dublin	Wayne	1,250			- 250	Gas well.
Dunkirk	Jay	± 925				Gas wells.
Dunreith	Henry					Gas well.
Earl Park	Benton	1,000	5			Abandoned.
Eagletown	Hamilton					Gas well; small product.
Eaton[14]	Delaware					Gas well.

[1] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 704.
[2] Ibid., pp. 709–713.
[3] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 736.
[4] Ibid., p. 722; U. S. Geol. Surv., 18th Ann. Rept., 1896–97, part 4, pp. 487–488.
[5] U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 721.
[6] Ibid., pp. 690–691.
[7] U. S. Geol. Surv., 18th Ann. Rept., 1896–97, part 4, p. 488; Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 725.
[8] Record, U. S. Geol. Surv., 11th Ann. Rept., part 1, 1889–90, p. 729.
[9] Ibid., p. 754.
[10] Borings preserved in county auditor's office.
[11] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 740.
[12] Ibid., p. 731.
[13] Record, Mich. Geol. Surv., 1881–1893, p. 54, pl. 14.
U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 713.

INDIANA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Edinburg[1]	Johnson	1,583			− 83	For gas; salt water only.
Elizabethtown	Bartholomew.	+ 914				Gas well.
Elkhart[2]	Elkhart	+ 615	5¼		Flowed.	For gas; unsuccessful. Salt water at 550 feet.
Elwood	Madison	± 936				Gas well.
English (8 miles south).	Crawford	700	3	11	+ 35	
Do	do	887	8	8	+ 50	
English, Clark well[3]	do	648				Gas at 408 feet; salt water at 648 feet; some oil.
Evansville	Vanderburg	1,100				Several wells; brackish water.
Do[4]	do	1,829				Salt water at 1,400 feet.
Do	do	1,500				
Fairmount[5]	Grant	500–1,000	8–4			Gas wells.
Farmland[6]	Randolph	1,017				Do.
Fisher's Station	Hamilton					Do.
Flora	Carroll	±1,100	6–4			Salt water at 1,040 feet; also oil.
Florida	Madison					Gas well.
Fontanet	Vigo	± 400	8		− 12	
Fontanet (one-half mile southwest).	do	440		Many.		
Fontanet (3 miles southwest).	do	1,451	8–4	Many.		Water at 400 feet.
Fortville	Hancock	(?)				Gas wells.
Fort Wayne	Allen	250–450		5,000 in all.	−6(?)	54 wells at waterworks.
Fort Wayne (Bass foundry.)	do	1,458				For gas; unsuccessful.
Fort Wayne (Abott's addition).[7]	do	1,900			−900	For gas; unsuccessful; mineral water.
Fort Wayne (courthouse).	do	3,000			− 8	For gas; unsuccessful.
Fountain City	Wayne	+1,025				Do.
Francesville	Pulaski	+890				Oil and gas; unsuccessful.
Frankfort[8]	Clinton	1,446			−600	Salt water at 1,200 feet.
Frankfort (4 miles east).	do	1,105				For gas; unsuccessful.
Franklin[9]	Johnson	1,113				
Frankton	Madison	840				Gas well.
Fulton	Fulton	1,150				Salt water only; abandoned.
Galveston[10]	Cass	860				
Do	do	934				Salt water only.
Garrett	Dekalb					Small gas well.
Glenwood	Rush	+950				For gas; unsuccessful.
Goshen[11]	Elkhart	2,059			Flows.	For gas; unsuccessful; salt water.
Gosport	Owen	926		Many	+30	White sulphur water.
Greencastle	Putnam	1,200	6			For gas; unsuccessful.
Do	do	2,000–2,700	8–4		Flow.	Several borings; water at several horizons.
Greenfield[12]	Hancock	990				Gas wells.

[1] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 728.
[2] Ibid., p. 735; Michigan Geol. Survey, 1881–1893, p. 57, Pl. XVII.
[3] Record, Ind. Geol. and Nat. Hist., 17th Ann. Rept., 1891, p. 311.
[4] Ky. Geol. Surv. Petroleum, Natural Gas, etc., by Orton, pp. 197–98.
[5] U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 685.
[6] Ibid., pp. 688–689.
[7] Analysis and record, Ind. Geol. and Nat. Hist. Surv., 16th Ann. Rept., 1888, pp. 129–130.
[8] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 730.
[9] Ibid., p. 727.
[10] Record, Ind. Geol. and Nat. Hist., 19th Ann. Rept., 1894, p. 39.
[11] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 735; Mich. Geol. Surv., 1881–1893, p. 60, pl. 19.
[12] Record, U. S. Geol. Surv., 11th Ann. Rept., part 1, pp. 701–702.

INDIANA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Greensburg[1]	Decatur	862–886				Numerous gas wells.
Greensboro (near)	Henry					Gas well.
Greentown	Howard	903				Do.
Greenwood	Johnson	600			− 45	Water from 320 feet.
Do.[2]	do	1,975			−240	For gas; unsuccessful; water at 1,840 and 1,865 feet.
Hagerstown	Wayne	706–1,025				Several gas wells.
Hammond	Lake	1,700–1,900				Several wells.
Hartford	Jay	±925				Gas wells.
Hartford City[3]	Blackford	900–1,000				Over 1,000 wells for oil and gas in the county.
Hartsville	Bartholomew	+861				Gas well.
Hebron	Porter					For gas; unsuccessful.
Herbst Station	Grant	1,045				Gas well.
Honey Creek	Henry	+980				Gas wells.
Huntington[4]	Huntington	1,037			− 87	For gas; unsuccessful.
Huntsville	Madison					Gas well.
Indianapolis	Marion	950–1,039				For gas; unsuccessful.
Do.[5]	do	1,520				Do.
Irvington	do	990				Gas well.
Jasper	Dubois	1,100	8			Salt water at 460 feet, gas at 600 feet, oil and mineral water at 955 feet.
Jeffersonville[6]	Clark	960–1,216				For gas; unsuccessful.
Joliet	Hamilton					Gas well; small flow.
Jonesboro[7]	Grant	935				Gas well.
Kempton[8]	Tipton	1,035				
Kendallville	Noble	+1,920				For gas; unsuccessful.
Kentland	Newton	1,200			− 60	
Do	do	1,325				Do.
Kewanna[9]	Fulton	1,089			− 84	Do.
Kirklin	Clinton	1,089				Do.
Knox	Starke	±1,500				Borings for gas or oil; unsuccessful.
Kokomo[10]	Howard	920–1,000		Many.	Flows.	Gas wells; much salt water.
Do	do			Many.		
Do	do				Flows.	
Knightstown	Henry					Gas well.
Lacrosse (3 miles distant).	Laporte	838			At surface.	Good water.
Lafayette[11]	Tippecanoe	410				
Do	do	1,000				Gas well.
La Fontaine[12]	Wabash	920				Gas well.
Lapelle	Madison					Do.
Laporte	Laporte					For gas; unsuccessful.
Larwell[13]	Whitley	1,593			−200	For gas; unsuccessful; salt water.
Lawrence	Marion	1,015			−315	
Lawrenceburg	Dearborn					Gas wells.
Lebanon[14]	Boone	1,350–1,840				Several wells; saline water at 400 and 1,350 feet.
Leesburg	Kosciusko	1,800	5			
Liberty[15]	Union	971	8–10			For gas; unsuccessful.

[1] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, pp. 703–704.
[2] Ibid., p. 728.
[3] Ibid., pp. 678–681.
[4] Ibid., p. 739.
[5] Record, Ind. Geol. and Nat. Hist., 1885–86, 15th Rept., p. 331.
[6] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 724.
[7] Ibid., p. 688.
[8] Ibid., p. 696.
[9] Ibid., p. 733.
[10] Ind. Geol. and Nat. Hist. Surv., 1885–86, 15th Ann. Rept., pp. 323–326; U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, pp. 891–893.
[11] Ind. Geol. and Nat. Hist. Surv., 1885–86, 15th Ann. Rept., pp. 69–71.
[12] Record, etc., U. S. Geol. Surv., 11th Ann. Rept., 1889–'90, part 1, pp. 689–690.
[13] Ibid., p. 736.
[14] Ibid., p. 730.
[15] Ibid., pp. 720–721.

INDIANA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Liberty (8 miles from).	Union	1,000	8-10			For gas; unsuccessful.
Lodi[1]	Fountain	1,155	10	35	+ 43	For oil; yields mineral water.
Logansport[2]	Cass	+1,075		2	Flows.	Several boring for gas; unsuccessful; sulphur water.
Loogootee	Martin	1,200				
Losantville	Randolph	1,105				For gas; unsuccessful.
McCordsville	Hancock					Gas well.
Madison[3]	Jefferson	1,004			—700	For gas; unsuccessful.
Marion[4]	Grant	+865-1,010	4		Flow.	Numerous gas wells; some yield oil.
Markle	Huntington	1,700	8		Flows.	White sulphur water.
Markleville	Madison	972				Gas well.
Martinsville	Morgan	1,472				For gas.
Do.[5]	do	668-704	5-6	30-35	Flow.	Six wells of mineral water.
Mechanicsburg	Henry					Gas wells.
Medaryville (6 miles west).[6]	Pulaski	1,030				Salt water and oil.
Michigan City	Laporte	819,833		300	+22	Temp., 57°. Sulphur water.
Michigan City (1 mile west).[7]	do	541				
Middleton	Henry	+935				Gas wells.
Mifflin[8]	Crawford	1,180				Some oil at 135 feet and some gas at 1,180 feet.
Millhousen	Decatur	1,000-1,100	6			Several gas wells.
Milroy						For gas; unsuccessful.
Millgrove	Jay	±925				Gas wells.
Mitchell	Lawrence	+1,200			—30	For gas; saline water at 1,200 feet.
Monon[9]	White	±920			Nearly to surface.	Salt water at 880 feet.
Do	do	+880			Nearly to surface.	Gas boring; salt water at 880 feet.
Monticello	do	+1,050			—550	Salt water at 1,050 feet.
Monrovia	Morgan	±1,500				
Montezuma	Parke	1,675	4	Many.	+115	Water at 450 and 1,100-1,200 feet.
Do	do	1,700		475	Rises to surface.	Salt water at 300 and 450 feet; sulphur water at 1,200 feet, which rose to +100 feet.
Monticello[9]	White	+1,150			—650	For gas; unsuccessful; salt water at 1,150 feet.
Montpelier[10]	Blackford	975			Flows.	Gas well; hard water.
Do	do	808				
Mooresville	Morgan	±1,500				
Morgantown	do	1,665	8		Nearly to surface.	Gas borings; fresh water at 70 and 490 feet; saline water at 1,100 feet.
Morristown[11]	Shelby	921			—421	Gas well; much salt water.
Mount Summit[12]	Henry	1,082			—720	Gas wells; salt water at 1,020 feet.

[1] Record, Ind. Agricultural and Geographical Repts., 1869, pp. 29-31.
[2] Record, Ind. Geol. and Nat. Hist., 19th Ann. Rept., 1894, p. 38; U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, p. 732.
[3] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, p. 723.
[4] Ibid., pp. 685-687.
[5] Record and analysis, U. S. Geol. Surv., 18th Ann. Rept., 1896-97, part 4, pp. 490, 498.
[6] Record, Ind. Geol. and Nat. Hist. Surv., 17th Ann. Rept., 1891, p. 315.
[7] Record, ibid. and U. S. Geol. Surv., 18th Ann. Rept., 1896-97, part 4, p. 491.
[8] Record, Ind. Geol. and Nat. Hist. Surv., 17th Ann. Rept., 1891, pp. 311-312.
[9] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-90, Part 1, p. 731.
[10] Ibid., p. 680.
[11] Ibid., p. 703.
[12] Ibid., p. 706.

INDIANA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Myers	Hamilton					Gas well; small product.
Muncie[1]	Delaware	870–965				Numerous wells in vicinity.
Do[2]	do	1,606			−506	Brine at 1,390 feet.
Nashville	Brown	500–530			Flows.	Two wells.
New Albany	Floyd					For gas; unsuccessful.
New Britton	Hamilton					Gas wells.
Newburg	Warwick	+400				
Newcastle[3]	Henry					Several gas wells with flows of salt water.
New Corner	Delaware					Gas well.
New Palestine	Hancock	1,060			−400	Salt water at 1,008 feet; some gas at 625 and 900 feet.
Noblesville[4]	Hamilton	843–860				Gas wells.
North Madison	Jefferson	1,500	6	Many.	−200	
North Manchester[5]	Wabash	+1,180			−190	Gas boring; unsuccesful; salt water.
North Vernon[6]	Jennings	+1,460			+260	Do.
Oakville	Delaware					Gas well.
Ogden	Henry					Do.
Osgood	Ripley	950	5			Gas boring; small supply.
Oxford (5 miles SW).	Benton	537				
Palestine[7]	Hancock					Gas well.
Paoli	Orange	1,000				Sulphur water at 250 feet; salt water at 900 feet; lithia water at 1,000 feet.
Parker (1 mile north)	Randolph					Do.
Pendleton[8]	Madison					
Perkinsville	Madison					Gas well.
Peru[9]	Miami	900–1,050			To surface.	Boring for oil and gas.
Peru (2½ miles north).[10]	do	1,042			−50	Salt water at 1,042 feet.
Petersburg	Pike	1,161				Blue lick water.
Do	do	1,200				Gas well.
Petersburg (one-half mile east).	do	1,310			Flows.	Salt water at 600 and 1,310 feet.
Petersburg (2½ miles northeast).	do	1,200			−80	Salt water at 600 feet.
Petersburg (one-half mile north).	do	1,200	10–5½	30	Flows.	Fresh water at 160 feet; salt water at 600 feet; oil at 1,200 feet.
Petersburg (1 mile north).	do	1,700	10–4		Flows.	Fresh water at 700 feet; some oil at 1,200 feet.
Pierceville	Ripley	965				For gas; unsuccessful.
Plainfield	Hendricks	1,365				Gas well.
Plymouth[11]	Marshall	+ 1,388			−468	For gas; unsuccessful.
Point Gabel	Grant					Gas well.
Portland[12]	Jay	900–1,500			−300	Gas wells; salt water at 1,500 feet.
Princeton	Gibson	600–790				Several wells.
Do	do	1,274				
Red Key	Jay	+900				Gas well.
Reelsville (near)	Putnam	2,600		Many.	Flows.	Sulphur water; no oil; temp., 60°.

[1] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, Part 1, pp. 713–719.
[2] Ibid., p. 731.
[3] U. S. Geol. Surv., 18th Ann. Rept., 1889–90, Part 1, pp. 705–707.
[4] Ibid, p. 697.
[5] Ibid, p. 739.
[6] Ibid., p. 723.
[7] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, p. 702.
[8] Ibid., p. 710.
[9] Record, Ind. Geol. and Nat. Hist. Surv., 16th Ann. Rept., 1888, p. 184; U. S. Geol. Surv., 11th Ann. Rept., 1889–90, Part 1, pp. 732–733.
[10] Record, Ind. Geol. and Nat. Hist. Surv., 16th Ann. Rept., 1888, pp. 185, 255.
[11] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, Part 1, p. 735.
[12] Ibid., p. 681.

INDIANA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Reelsville (near)[1]	Putnam	1,240			+20	Salt and sulphur water.
Rensselaer	Jasper	800				Sulphur water.
Do	do	1,275				Gas boring: not in use.
Ridgeville	Randolph	981–1,105				Gas borings; unsuccessful.
Richmond	Wayne	945				Gas boring: unsuccessful.
Rochester[2]	Fulton	1,185				For gas: unsuccessful.
Do	do	500		Many.	+ 5	Sulphur water.
Rochester (1¼ miles south).	do	1,157			−15	Salt water at 1,157 feet.
Rochester	do	1,500				Water flowed at 240 feet; well abandoned.
Rockport	Spencer	+400				Four gas borings; no product.
Rockville	Parke	2,169				For gas; unsuccessful.
Rogers	Pike	1,785	10–4½			
Royal Center[3]	Cass	+925				Oil wells.
Royerton	Delaware					Gas well.
Rushville and vicinity.[4]	Rush					Gas wells.
St. Omer	Decatur					Gas well.
St. Paul	Shelby	+820				Do.
Salem[5]	Washington	1,800				For gas; unsuccessful.
Do	do	750				Gas well.
Sandusky	Decatur	830	6		−15	
Selma[6]	Delaware	1,025				Do.
Seymour[7]	Jackson	1,090–1,204			Flows.	Several gas wells.
Do	do	500				Sulphur water.
Sharpsville[8]	Tipton					
Shelbyville[9]	Shelby					For gas; unsuccessful.
Shideler	Delaware					Gas well.
Sheridan	Hamilton	1,076				Do.
Shoals	Martin	960			Flows.	Some salt water.
Somerset[10]	Wabash	853				Water at 485 feet.
South Bend[11]	St. Joseph	1,670				For gas; unsuccessful.
Spencer	Owen	1,150	4	200	+65	Several wells; saline water.
Spiceland[12]	Henry					Gas wells.
Springport[13]	do					For gas; unsuccessful.
St. Marys	Vigo	2,055	8		−75	
Do	do	830	8		−75	
Sullivan	Sullivan	1,000			−15	Gas boring; much strong brine.
Sullivan, 2 miles SE	do	±1,000			Flows.	
Sullivan[14]	do	544				
Sulphur Springs	Henry					For gas; unsuccessful.
Summitville	Madison					
Do	do	1,000	8–6		At surface.	
Do.[15]	do	971			Flows.	Gas well; water at 140 feet.
Swainville	Hamilton			370		Gas well; small product.
Swayzee	Grant					Gas wells.
Sweetzer	do					Gas well.
Sycamore	Howard					Do.
Tampico	do	+950				Gas wells.

[1] Record Ind. Agr. and Geol. Rept., 1869, pp. 29–31.
[2] Record U. S. Geol. Surv., 11th Ann. Rept., 1889–90, Part 1, p. 733.
[3] U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 732.
[4] Ibid., p. 704.
[5] Ibid., pp. 725–726.
[6] Ibid., pp. 715–716.
[7] Ibid., pp. 726–727.
[8] Ibid., p. 969.
[9] Ibid., pp. 702–703.
[10] Record, Ind. Geol. and Nat. Hist. Surv., 17th Ann. Rept., 1891, pp. 252–253.
[11] Record, Michigan Geol. Surv., 1881–1893, p. 84, pl. 64; U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, pp. 734–35.
[12] Ibid., p. 707.
[13] Ibid., p. 706.
[14] Record, Ind. Geol. Surv., 1870, pp. 193–194.
[15] Record, U. S. Geol. Surv., 11th Ann. Rept. 1889–90, part 1, p. 709.

INDIANA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Terre Haute[1]	Vigo	2,800	8		Flows.	Sulphur water with little gas.
Do.[2]	do	1,793				Brine at 1,360 feet; sulphur water at 1,793 feet; some oil at 1,629 feet.
Do	do	1,625				Several borings for oil; unsuccessful.
Thorntown	Boone	1,500	6	5	Flows.	For gas; unsuccessful.
Tipton[3]	Tipton	1,030				Small amount of gas.
Tobasso Landing	Floyd					Gas wells.
Trafalgar	Johnson	1,500				Dry well.
Treaty	Wabash	950	8-5			
Do.[4]	do	900	8-6		+8	
Union Grove	Delaware	944				Gas well.
Union City[5]	Randolph	1,093-1,780				Several borings for gas; unsuccessful.
Upland	Grant	1,040				Gas well.
Valley Mills	Henry					Do.
Valparaiso[6]	Porter	1,344				Do.
Do.[7]	do	1,336				For gas; unsuccessful.
Van Buren[8]	Grant	973				Gas well.
Vernon	Jennings	923				For gas; unsuccessful.
Wabash[9]	Wabash	2,270	6		−40	For gas; unsuccessful.
Waldron	Shelby	+820				Gas well.
Walnut Level	Wayne	+867				For gas; unsuccessful.
Walton	Cass	1,028				Salt water and some oil.
Warren	Huntington	969				Some oil; abandoned.
Warsaw[10]	Kosciusko	700		15		For gas; unsuccessful.
Do.[11]	do	1,437			−387	Salt water.
Washington	Wayne	+976				For gas; unsuccessful.
Waterloo	Dekalb					Gas well.
Westfield	Hamilton	1,080				Gas wells; much salt water.
Do	do	1,068				Gas wells.
Williamsport	Warren	1,200			Flows.	Gas well; salt and fresh water also.
Winamac	Pulaski	1,200		45	do	For gas; unsuccessful; flow of water also.
Winchester[12]	Randolph	1,000-1,071				Several gas wells.
Windfall	Tipton	1,002				Gas well.
Worthington	Greene	1,445			Flows.[?]	Sulphur water.
Xenia[13]	Miami	937				Gas wells; flow of water also.
Do	do	936				Do.
Yorktown	Delaware	940				Gas well.
Zionsville[14]	Boone	1,038			−438	For gas; unsuccessful; salt water at 1,013 feet.
Do	do	800			Flows.	For gas; unsuccessful.

[1] Record, Ind. Geol. Surv. Report for 1870 (Indianapolis, 1871), pp. 126-134.
[2] Record, Ind. Geol. Surv. Report for 1870 (Indianapolis, 1871), p. 126; Ind. Agr. and Geol. Surv. Rept., 1869, pp. 28-29, 31; Am. Jour. Science, 2d series, vol. 48, p. 271.
[3] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-1890, part 1, pp. 695-697; Ind. Geol. and Nat. History Surv., 1885-1886, 15th report, p. 330.
[4] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-1890, part 1, p. 714.
[5] Ibid., p. 684.
[6] Ibid., p. 733.
[7] Record, Ind. Geol. and Nat. History Surv., 16th Ann. Rept., 1888, p. 264.
[8] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-1890, part 1, p. 689.
[9] Indiana Geol. and Nat. Hist. Surv., Report for 1875, pp. 43-48.
[10] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, p. 739.
[11] Ibid., p. 736.
[12] Ibid., pp. 683-685.
[13] Ind. Geol. and Nat. Hist., 16th Rept., 1888, p. 187.
[14] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, p. 730.

²AL PUBLICATIONS RELATING TO DEEP BORINGS IN INDIANA.

al Gas Field of Indiana, by A. J. Phinney, United States Geological enth Annual Report, 1889–1890, part 1, pp. 579–740. Plates. Wash-

ources of Indiana and Ohio, by Frank Leverett, United States Geo-y, Eighteenth Annual Report, 1896–1897, part 4, pp. 423–559. Plates. , 1897.

INDIAN TERRITORY.

.	Nation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
miles	Cherokee	1,800		Few.	Flows.	Small quantity crude petroleum.
e W.)	do	300–600	8			Several oil wells.
SE.)	do	470			Flows.	Salt water.
	do	520			do	Do.
	Chickasaw	876	10			Salt water at 298 feet; no water below; well in progress.
W.)[1]	Choctaw	1,414				Small indications of oil at 807 feet; oil at 917 feet; much salt water; salt water and oil at 1,235 feet and 1,347 feet; oil and gas at 1,391 feet.

IOWA.

.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
	Hardin	920				
	Kossuth	1,050			−69	
	Iowa	1,640		100	+30	Temp. 60°.
	Jones	2,007	10–5	300	−56	
	Cass	486		Many.		Coal prospect.
	do	1,310		do	−160	
	Carroll	620				Failure.
	Boone	3,016		Many.	−200	
	Taylor	425				Coal prospect.
	Hancock	684	7		−16	
	do	535	4½		−510	
	Des Moines	2,430	6–5	70	−38	
	Winneshiek	1,140	4	70	−320	
	do	1,223	8		−100	
	Linn	1,450	5	150	+14	3 wells.
	Appanoose	2,495	12–4	200	−260	
	do	1,540	14–7	350	−280	
	Cherokee					
	Page	1,002			Flowed.	Coal prospect.
	Clinton	1,035–1,497	10–5	1,736	+68	5 wells.
	do	1,065	5½		+35	
	do	1,674	8–5	1,500	+45	
[13]	Pottawattamie.	1,114				
	do	860				
school	do	1,091	4	56	+50	
	Howard	1,158				

[1] Geol. Surv. Reports, vol. I⁵, p.
Geol. Surv., vol. 3, pp. 189–192;
19–220.
196.
287.
295.
339.
a Geol. Surv., vol. 6, p. 195.

[8] Record and analysis, ibid., pp. 191–192.
[9] Record and analysis, ibid., pp. 326–328.
[10] Record and analysis, ibid., pp. 326–328.
[11] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 811; analysis, ibid., p. 827.
[12] Ibid., p. 811; analysis, ibid., p. 827.
[13] Analysis, Iowa Geol. Surv. Reports, vol. 6, p. 340.
[14] Ibid., p. 340.

IOWA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Creston	Union	500-600				Two borings for coal; unsuccessful. Found water.
Des Moines[1]	Polk	3,000	10-3	400	—45	
Davenport (bottling works).[2]	Scott	780		300	+59	
Davenport (Malt and Grain Co).[3]	do	1,076	5	300	+13	Water from 1050-1076 feet.
Davenport (Gas Company).[3]	do	1,200	5-4	400	+47	Two wells. Water from near bottom.
Davenport (Glucose Co.).[4]	do	2,100-2,107	5		+77	Four wells.
Do.[5]	do	1,500	5	250	+51	
Davenport (city park).[6]		1,797	5	+125	—22	Water at 1,175 feet.
Davenport (Kimball House).[7]		1,080	5	120	+20	Water at 1,075 feet.
Davenport (packing company).[8]		1,180	8-5	250	+45	
Davenport (Schmidt building).[8]		1,200	4	73	+24	
Davenport (woolen mills).[8]		1,053	3¼	300	+35	Water from 700 and 1,050 feet.
Davenport (ice company).[8]		1,067	6-4	240	+10	Water from 775 and 1,064 feet.
Dubuque[8]	Dubuque	802	4			Water at surface.
Do.[9]	do	955	6	340	+81	Several wells of about this depth.
Do	do	1,262	6	450		
Do.[9]	do	1,954	3	40	+1	
Do	do	1,300-1,400	13	2,000	Flow.	Two wells.
Do.[10]	do	1,765	3	40		
Do.[9]	do	1,000	5	580	+41	Several wells 965-1,060 feet.
Emmetsburg[11]	Palo Alto	874			—34	
Do	do	810	6	42	—26	
Farmington	Van Buren	705				
Fontanelle	Adair	800		None.		Abandoned.
Fort Madison[12]	Lee	689	6	600	+20	
Do.[13]	do	720	6		+85	Temp. 55°.
Do.[13]	do	764	4		+20	
Glenwood[14]	Mills	2,000	10-4	83	—173	
Do.[14]	do	1,910		80	—5	
Granville	Sioux	450		Many.	150	
Greenfield	Adair	900		None.		Coal prospect.
Do	do	512		None.		
Grinnell[15]	Poweshiek	2,003	10-4	105	—230	
Grundy Center	Grundy	485			—150	
Holstein[16]	Ida	2,004	8-4		—275	
Homestead[17]	Iowa	2,224	10-4		—117	
Hull[18]	Sioux	1,230	10-6		—100	
Jefferson	Greene	2,021	8 5		—40	
Keokuk[19]	Lee	710	6	250	+35	Temp. 64°. Two other wells 700 feet deep.
Do.[20]	do	800	6		+47	Temp. 50°.
Do.[20]	do	2,000	12-10	{3 wells 1,700}	+30	Temp. 65°; 3 wells.

[1] Record, Iowa Geol. Surv. Reports, vol. 6, pp. 294-299.
[2] U. S. Geol. Surv., 17th Ann. Rept., 1895-1896, part 2, p. 812.
[3] Ibid., p. 812.
[4] Record, U. S. Geol. Surv., 17th Ann. Rept., 1895-96, part 2, p. 842.
[5] Ibid., p. 811.
[6] American Geologist, vol. 3, 1889, p. 117; Iowa Geol. Surv. Reports, vol. 6, pp. 272-280; Record U. S. Geol. Surv., 17th Ann. Rept., 1895-96, part 2, pp. 842-845.
[7] Record, U. S. Geol. Surv., 17th Ann. Rept., 1895-96, part 2, p. 844.
[8] Record and analysis, Iowa Geol. Surv. Reports, vol. 6, pp. 208-214.
[9] Ibid., pp. 208-214.
[10] Ibid., pp. 208-211.
[11] Record, ibid., p. 196.
[12] Record and analysis, Iowa Geol. Surv. Reports, vol. 6, pp. 321-322.
[13] Ibid., pp. 321-322.
[14] Ibid., pp. 340-347.
[15] Record and analysis, ibid., pp. 287-292.
[16] Record, ibid., p. 222.
[17] Record and analysis, ibid., pp. 283-285.
[18] Record, ibid., p. 199.
[19] Record and analysis, ibid, pp. 323-326.
[20] Ibid, pp. 323-326.

IOWA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Keokuk[1]	Lee	2,230	10	300	+30	Another well 1,805 feet; water also at 600 and 900 feet.
Do	do	1,987	6–4			
Do	do	935		Many.	Flow.	
Lakepark	Dickinson	700	4	55	−300	Temp. 50°.
Lansing[2]	Allamakee	676 740	6	700	+40	Two wells.
Le Mars[3]	Plymouth	1,560				
McGregor[4]	Clayton	1,008	6–3	20	+62	Temp. 54°.
Do.[5]	do	520	6–3		+20	Temp. 52°.
Manchester[6]	Delaware	1,870	10–5		−14	
Mason City	Cerro Gordo.	600	6–4	60	No flow.	Three wells.
Do	do	1,200	8	80	No flow.	
Do.[5]	do	1,473	8–6		−75	
Monota	Clayton	417	6	70	−212	
Do	do	452	6	None.		Abandoned.
Monticello[6]	Jones	1,198		175	−40	
Mount Clara[7]	Lee	939			−10	Formerly flowed 200 gallons.
Mount Pleasant[8]	Henry	1,125		165	−30	
Nevada	Story	940	11–6		−49	
Newton[9]	Jasper	1,400	5	Many.	−90	
Osceola	Clarke	1,953			No flow.	
Oskaloosa[10]	Mahaska	2,800–3,000				Abandoned.
Ottumwa[11]	Wapello	2,047	8	700	+108½	Temp. 70°.
Do.[10]	do	1,554	10–4		+49½	Temp. 64°.
Pella[12]	Marion	1,803	12–5	250	−90	
Pocahontas (3 miles south).	Pocahontas	632				Unsuccessful.
Pocahontas (near)	do	1,300		Many.		
Postville[13]	Allamakee	515	8½		−300	
Redoak	Montgomery	560				Coal prospect.
Sabula[14]	Jackson	973		720	+78	
Sanborn	O'Brien	1,224	6	80	−459	
Saylorville	Polk	1,800				
Shenandoah	Page	700				
Sibley	Osceola	763	4½	100	-200	
Sigourney[15]	Keokuk	1,880	6–4½		−30	
Sioux City[16]	Woodbury	2,011		3	Flows.	Water at 570 and rose to −12; at 1,250 feet flowed.
South English	Keokuk	420	4	None.		Abandoned.
Spencer	Clay	800	6	Many.		
Spencer	do	400				
Spencer (10 miles south).	do	600	4½–3½			Abandoned.
Tipton[17]	Cedar	2,700	8–4½	Many.	−65	
Vinton[18]	Benton	1,287	6	62	+28½	Temp. 56°.
Do.[19]	do	1,425	6	50	+28	Do.
Wall Lake	Sac	427				
Washington[20]	Washington	1,611	10–4½	95	−54	
Do.[21]	do	1,217	12–6	62	−58	
Waukon[22]	Allamakee	577	8		−280	
Waverly	Bremer	1,720		Many.		
Webster City[23]	Hamilton	1,250	8–6	70	+16	
West Liberty[24]	Muscatine	1,768	6–4⅛	½	Flows.	Temp. 65°.
Whatcheer	Keokuk	636				
Wilton Junction[25]	Muscatine	1,300	8–6	300	−78	
Bellville Township	Pocahontas	1,300				Abundant supply.

[1] Record, Iowa Geol. Sur. Reports, vol. 5, p. 200.
[2] Ibid., pp. 232–235.
[3] Record and analysis, ibid, pp. 185–188.
[4] Ibid., pp. 214–219.
[5] Ibid., pp. 193–195.
[6] Record and analysis, ibid., p. 256.
[7] Record, ibid., p. 322.
[8] Record and analysis, ibid., pp. 320–321.
[9] Record, ibid., p. 292.
[10] Ibid., pp. 308–310.
[11] Record and analysis, ibid., pp. 317–320.
[12] Record, ibid., pp. 310–315.
[13] Ibid., p. 189.
[14] U. S. Geol. Surv., 17th Rept., 1895–96, part 2, p. 817.
[15] Record, Iowa Geol. Surv. Reports, vol. 5, pp. 305–308.
[16] Record, Iowa Geol. Surv. Reports, vol. 5, p. 258.
[17] Ibid., vol. 6, pp. 261–262.
[18] Ibid., vol. 3, pp. 192–195.
[19] Record and analysis, ibid., vol. 6, pp. 266–267.
[20] Record and analysis, Iowa Geol. Surv. Reports, vol. 6, pp. 304–305; Am. Geologist, vol. 1, pp. 28–31.
[21] Record and analysis, Iowa Geol. Surv., Reports, vol. 6, pp. 304–305.
[22] Record, Iowa Geol. Surv. Reports, vol. 6, p. 202, 1896.
[23] Record and analysis, ibid., pp. 220–222.
[24] Records and analysis, Iowa Geol. Surv. Reports, vol. 6, pp. 281–282.
[25] Ibid., pp. 280–281.

PRINCIPAL PUBLICATIONS RELATING TO DEEP BORINGS IN IOWA.

Iowa Geological Survey, volume 3, Second Annual Report, 1893, with accompanying papers, 502 pages, plates, Des Moines, 1895.

Artesian Wells of Iowa, by W. H. Norton, Iowa Geological Survey, volume 6 pages 113–428.

The Water Resources of Illinois, by Frank Leverett, United States Geological Survey, Seventeenth Annual Report, 1895–96, part 2, page 811.

KANSAS.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Alma	Wabaunsee	2,000				
Do	do	1,912	4–2¼		Flows.	Salt water and gas.
Anthony[1]	Harper	2,335				
Asherville	Cloud	638	3		−26	Salt water from 50 to 638 feet; mainly blue clay.
Atchison	Atchison	+1,197				
Banner	Trego	438	6	Few.	−150	All in shale.
Benedict (southeast of).	Wilson	2,414	13-6¼			Fresh water at 403 feet; strong salt water at from 1,096 to 2,414 feet.
Benedict (near)	do	827	8¼–5	1½		Oil well; fresh and salt water also found.
Bronson	Bourbon	850	8–6			Salt water at 650 to 700 feet.
Buffalo	Wilson	1,170				Only salt water.
Buffalo (2 miles west)	do	400–800				Oil and water wells.
Caldwell	Sumner	800	6			Salt water only at 457 feet.
Cawker City (2 miles northeast).	Mitchell	468			−217	Salt water.
Cawker City (10 miles north).	do	416			No flow.	Do.
Chanute[2]	Neosho	982				Several gas and oil wells.
Do	do	806	6¼–5			Large flow of gas; some water.
Cherokee	Crawford	913	7	500	−100	First water at 650 feet.
Cedarville	Smith					
Cherryvale	Montgomery	609–617				Gas wells.
Do.[3]	do	1,220	1½		+8	Salt water, and gas found.
Do	do	1,397–1,500				Oil wells; water at several horizons.
Coffeyville	do	550				Gas well.
Columbus	Cherokee	1,304			−65	
Coolidge	Hamilton	500	5¼	90	Flows.	
Devon (near)	Bourbon	800	8–6			Salt water at from 650–700 feet.
Dodge City (1½ miles east).	Ford	800				Unsuccessful.
Doniphan[4]	Doniphan	763				
Eldorado	Butler					Deep boring, salt water.
Elgin	Chautauqua	+1,400				Abandoned.
Elkader	Logan	408				
Elkader (7 miles S.)	do	500				Unsuccessful. All in blue shale.
Ellsworth	Ellsworth	1,300				Salt 730–880 feet; salt water at 1,300 feet.
Do	do	730	4½		−114	Salt water.
Emporia[5]	Lyon	2,005	6			Gas prospect; abandoned.
Eminence	Finney					
Erie	Neosho	750		400		Mineral water.
Erie (2 miles north)	do	833		Many.	Flows.	Large flow of oil and gas, and salt water.

[1] Record, Kansas Univ. Geol. Surv. Rept., vol. 1, Pl. 21.
[2] Ibid., vol. 1, p. 77, pl. 13; vol. 3, pl. 25.
[3] Ibid., vol. 1, pl. 11; vol. 3, pl. 22.
[4] Record, Kansas Univ. Geol. Surv. Report, vol. 1, pl. 18.
[5] Ibid., vol. 3, pl. 28.

KANSAS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Erie	Neosho	513				Salt water at 400 feet; oil sand at 550–585½ feet.
Eureka [1]	Greenwood	503				Coal prospect; abandoned.
Do	do	+1,100				In progress 1900; salt water 500–700 feet, and 800–900 feet.
Fall River	do	986	10–5½	1,000	−77	Water at 416 feet; salt water at 972 feet.
Do [2]	do	1,480		Many.		
Farlington	Crawford	556				Small flow of gas.
Farlington (2 miles southeast).	do	551				Small flow of oil.
Fleming	do	1,005½	6	Many.	−118	Water also at 800 feet.
Fort Scott	Bourbon	620	5½		Flows.	
Do	do	543	5½	4	Flows.	
Fort Scott (near)	do	750	6½			Gas well; strong flow of water.
Do	do	850–900	8–6			Oil wells; salt water.
Fowler	Meade					
Fredonia [3]	Wilson	1,224				
Do	do	2,414		None.		Salt water at 354 and 1,195 feet; abandoned.
Garden City (one-half mile NW.). [4]	Finney	+1,000				
Do	do	902				
Garden City (8 miles south).	do	1,250				
Girard [5]	Crawford	500–550				Two gas wells.
Do	do	857–900	10	Many.	−150	
Girard (3½ miles N.)	do	401				Gas.
Goode (7 miles SE.)		430			−70	
Goodwater	Gove	501	3	Few.		All in shale; abandoned.
Greatbend (4 miles northeast).	Barton	1,365		10	+30	Saline water from Dakota sandstone, at 344 feet.
Hill City (3 miles from).	Graham	400			No flow.	Shale to bottom.
Horton	Brown	1,100	6	Few.		Water at 45 feet.
Howard	Elk	1,000		None.		Abandoned.
Do. [6]	do	1,226–1,410				
Hoyt	Jackson	1,206 or 1,406 [?]	6	None.		
Humboldt [7]	Allen	793–962		Many.		Three water wells.
Do	do	937–970				Gas wells; water at 145, 218, 645 feet; salt water at 970 feet.
Hutchinson	Reno	+800				Several salt wells.
Independence	Montgomery	1,020				Oil and gas.
Iola	Allen	870				Large flow of gas.
Do [8]	do	734–737				Three wells.
Iola (near)	do	908	8¼–5			Large flow of gas.
Do	do	928	5			Salt water found.
Do	do	976				
Ionia	Jewell	432				Salt water: abandoned.
Jamestown	Cloud				Flows.	Salt water found.
Jerome	Gove	400				
Jetmore	Hodgeman	1,000				For coal.
Do	do	700 or 800			−20–30	Not in use; abandoned.
Johnson	Stanton	400	8	Many.	−180	
Kanopolis	Ellsworth	881	8–4			Salt water at 645–875 feet.
Kansas City [9]	Wyandotte	758				
Kendall	Hamilton	500				No water at that depth.

[1] Record, Kansas Univ. Geol. Surv. Report, vol 3, pl. 27.
[2] Ibid., vol. 1, pl. 12; vol. 3, pl. 24.
[3] Ibid., vol. 1, pl. 13; vol. 3, pl. 25.
[4] Ibid., vol. 2, p. 27.
[5] Ibid., vol. 3, p. 148.
[6] Ibid., vol. 3, pl. 29.
[7] Ibid., vol. 1, pl. 14; vol. 3, pl. 23.
[8] Ibid., vol. 1, pl. 15.
[9] Ibid., vol. 1, pl. 18.

KANSAS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Kincaid	Anderson	992				
Kingman	Kingman	+800				Salt shafts.
Kirwin	Phillips	514				
Lacrosse	Rush	444	3	20	−240	Water pure.
Laharpe[1]	Allen	990				
Larned	Pawnee	756		400		
Do	do	743	10–3	250	+50	Temp. 65°; salt water.
Lawrence	Douglas	600				Salt water.
Do	do	900				Gas and salt water.
Leavenworth[2]	Leavenworth	1,170			Flows.	Gas and water.
Do	do	2,116				
Liberal[3]	Seward	485	7	52	−130	Water at 130 feet.
Little River	Rice	1,000	8			Much water to 400 feet, then 600 feet of salt and shale.
Lone Elm	Anderson	1,140				Salt water at 320 feet, no gas or oil; abandoned.
Lovewell (3½ miles northwest).	Jewell	400				Salt water only.
Lyndon[4]	Osage	1,007				Salt water at 230 feet.
Lyons	Rice	1,230				Salt prospect; abandoned.
Lyons (Bemis Salt Co.).	do	1,625	8–5		−30	Salt well.
McFarland[5]	Wabaunsee	2,006	4			
Madison	Greenwood	1,896½	6			For gas; unsuccessful.
Mankato	Jewell	500	8		−50	Salt water.
Mapleton[6]	Bourbon	665				Water at 218 and 616 feet; oil at 647 feet, and salt water at 665 feet.
Marion	Marion	1,800				For coal; unsuccessful.
Marquette	McPherson	400	6	Few.	−70	Salt water.
Marysville	Marshall	1,380		Few.	Flows.	
Meade	Meade	800	6			Red beds at 200 feet; salt below.
Moran	Allen	1,008–1,085	12–4			Two holes; water to surface.
Mound Valley[7]	Labette	762	7½–6½	1½	+6	Temp. 70°. Salt water and gas.
Neodesha[8]	Wilson	1,101	8½–5			Oil prospect. Water at 230 and 820 feet; salt water at 420, 685, and 775 feet, and gas at 655 feet.
Do	do	±2,400	8½			
Do	do	1,310				
Do	do	2,414	6½	Many.		Sulphur water at 1,423 feet; salt water below.
Neodesha (near)	do	1,078	6½–5			Oil and gas wells. Water at 811 and 1,078 feet.
Neosho Falls	Woodson	1,2?5				Salt water at 361 feet.
Ness City (4 miles north).	Ness	656	3	30	−356	
Ness City (8 miles south).	do	±400	6			
Newton	Harvey	1,045				Prospect borings.
Do	do	910–1,076				Do.
Niotaze[9]	Chautauqua	1,158				Abandoned; flowed oil and water.
Oakley	Logan	725			−30	Unsuccessful; water at intervals to 200 feet, then shale to bottom.
Oberlin	Decatur	800–1,000		−½		

[1] Record, Kansas Univ. Geol. Surv. Report, vol. 1, pl. 14; vol. 3, pl. 23.
[2] Ibid., vol. 1, pl. 20; vol. 3, pl. 26.
[3] Record, 51st Congress, 1st sess., Senate Ex. Doc. No. 222, p. 158.
[4] Record, Kansas Univ. Geol. Surv. Report, vol. 3, pl. 27.
[5] Ibid., vol. 1, pl. 19; vol. 3, pl. 30.
[6] Ibid., vol. 1, pl. 16.
[7] Ibid., vol. 1, pl. 10; vol. 3, pl. 21.
[8] Ibid., vol. 1, pl. 11; vol. 3, pl. 22.
[9] Ibid., vol. 1, pl. 12; vol. 3, pl. 24.

KANSAS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Olathe	Johnson	600				Water at 85 feet; salt water at 580 feet; weak flow of gas at 361½ feet.
Osage Mission [1]	Osage	700				
Osborne	Osborne	500				
Oswego [2]	Labette	985	6		−100	Small amount of gas at 585 feet; salt water at about 610 feet.
Do	do	606			−40	Small amount of gas at 548 feet; salt water at 606 feet.
Ottawa	Franklin	1,002	8			Oil at 675 and 702 feet; large volume of gas.
Do	do	1,065				Salt water at 384 and 622 feet; fresh water at 715 and 755 feet; gas and water at 490 feet.
Paola [3]	Miami	1,075				City well.
Do	do	500–580	5¼–4¼	Many.	−0 to −400	Several gas wells
Parsons and vicinity.	Labette	500–1,050				Several wells for gas; not much found; salt water at 400 to 500 feet; no flow; abandoned.
Peru	Chautauqua	1,240–1,700				Three wells.
Peru (near)	do	1,190				Water at 660 and 1,190 feet.
Pittsburg	Crawford	950	7¼	75	−80	
Pleasanton	Linn	729	5			Salt water.
Do	do	918	6½			Salt water at 828 and 918 feet.
Pleasanton (near) [4]	do	757	6¼–5			Water at 132 and 656 feet; salt water at 348 and 757 feet, and trace of oil at 353 and 730 feet.
Portis (6 miles northwest).	Osborne	546			No flow.	Salt water.
Portis (8 miles northwest).	do	543	6		−200	Do.
Pratt	Pratt	±800			−15	Thick salt beds 600 to 800 feet; not used.
Pyramids (near)		408	8		No flow.	Bad water.
Ransom	Ness	653	6–3	Several.	−60	Water in sandstone under blue shale.
Randolph	Riley	400				
Ravanna (north of)	Finney	+400		Many.	−200	Abandoned.
Do	do	+400			−45	Do.
Richfield [5]	Morton	670		22	Flows.	
Do	do	700		3	Flows.	
Do	do	600		6	Flows.	Temp. 66°; water at 570 feet.
Do	do	640		15	+25	Two wells; temp. 60°.
Rago	Kingman	1,000				Salt well; 175 feet of salt.
Russell	Russell	997	10–5	Many.	−300	Saline water.
St. Marys	Pottawatomie.	1,123			Flows.	Salt water.
Do	do	520			Flows.	Do.
St. Paul	Neosho	661–668			Flows.	Salty water; abandoned.
Santa Fe	Haskell	1,200	6	Many.	−200	Good water at 200 and 400 feet.
Do	do	1,300	10–5¼		−100	
Scandia	Republic	1,003			−16	Good water.
Smith Center	Smith	600	7		−390	Salt water at 590 feet; abandoned.
Smith Center (2 miles southeast).	do	540		Many.	−140	Salt water from sand 535–540 feet under 535 feet of shale.

[1] Record, Kans. Univ. Geol. Surv. Report, vol. 1, pl. 15.
[2] Ibid., pl. 10; vol. 3, pl. 21.
[3] Ibid., vol. 1, pl. 17.
[4] Ibid., pl. 16.
[5] Record, 51st Cong., 1st sess., Senate Ex. Doc. No. 222, p. 157.

KANSAS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Sterling	Rice	916	10-2¼	None.	.....	Salt well.
Do	do	946	10-2¼	Few.	−3	Do.
Stover	Labette	530	7	.....	−16	
Sun (southwest of)	Barber	600	.....	.....	.....	For coal; unsuccessful; mostly black shale.
Syracuse	Hamilton	1,000	.....	.....	−90	
Thayer	Neosho	825	.....	.....	.....	Oil wells.
Thayer (near)	do	1,064	6¼-4¼	.....	.....	Water at 376, 575, 805, and 1,064 feet.
Do	do	895	8¼-6¼	.....	.....	Water at 215 feet; gas at 827–830 feet.
Tonganoxie	Leavenworth	854	.....	.....	.....	City well.
Topeka[1]	Shawnee	900	.....	.....	.....	
Do.[2]	do	1,638	.....	.....	.....	Coal prospect: no coal: no flowing water.
Toronto[3]	Woodson	1,452	.....	.....	Flows.	Salt water and some oil.
Do	do	940–782	.....	.....	.....	Two wells; some gas.
Tribune	Greeley	500	.....	.....	.....	Unsuccessful.
Valley Falls	Jefferson	1,174	3	2	+40	Very saline water.
Wallace (vicinity)	Wallace	300	4	None.	.....	Did not reach bottom of shales.
		448	7	.....	.....	
		460	7	None.	.....	
Wamego	Pottawatomie	1,000	.....	.....	+6	Salt water.
Washington	Washington	1,100–1,200	.....	1	.....	
Do	do	1,350	6	None.	.....	Abandoned.
Do	do	2,200	6	None.	.....	Do.
Weir City	Cherokee	442	8¼	75	−70	
Do	do	480	7¼	75	−70	
Do	do	490	6¼	.....	−70	
Wellington	Wabaunsee	1,000	.....	.....	.....	Not in use.
Wichita	Sedgwick	1,035	14–4¼	.....	−70	Salt water at 500 feet.
Do	do	1,025	.....	.....	.....	
Wilson	Ellsworth	1,375	8–5	.....	.....	Salt water; abandoned.
Winfield	Cowley	1,200	.....	Many.	+6	Salt water.
Yale	Crawford	1,217	6	Many.	−115	
Vulcan Iron Works	Kingman	1,000	.....	.....	.....	Two salt shafts.
———	Trego	700	.....	.....	.....	

PUBLICATIONS RELATING TO DEEP BORINGS IN KANSAS.

Report of J. W. Gregory, field agent for the Middle Division, Fifty-first Congress, first session. Senate Ex. Doc. No. 222, pp. 145–172. Washington, 1890.

Water Resources of a portion of the Great Plains, by Robert Hay, United States Geological Survey. Sixteenth Annual Report. 1894–95, part 2, pp. 535–588, plates. Washington, 1895.

The University Geological Survey of Kansas, by Erasmus Haworth and assistants. vol. 1. 320 pages, plates. Topeka, 1896.

Report of the Board of Irrigation, Survey, and Experiment for 1895 and 1896 to the Legislature of Kansas. 238 pages, plates. Topeka, 1897.

The University Geological Survey of Kansas. Special Report, by Erasmus Haworth and W. R. Crane. vol. 3. 347 pages, plates. Topeka, 1898.

[1] Record, Kans. Univ. Geol. Surv. Report, vol. 1, pl. 17.
[2] Ibid., vol. 3, pl. 27.
[3] Ibid., vol. 3, p. 149, pl. 29.

KENTUCKY.

	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gals.*	*Feet.*	
miles	Boyd	1,715	13-10			For oil or gas; unsuccful.
miles	do	2,100	13-10			Do.
west)[1]	Boyle	+1,414				Oil and gas.
miles	Ohio	900				No oil or water; abandoned.
outh[2]	Lawrence	2,597				For oil or gas; unproductive.
outh	do	1,840				Do.
[1,2]						
[4]	Warren	1,782				But little oil, gas, or water.
(vi-	do	600-1,200				Several prospects for oil or gas; some gas.
1 (15 est).	do	600-700				Several wells yielding heavy oil.
g [8]	Meade	500-579				Several gas wells.
	Bracken	600				For oil or gas; in progress 1899.
tion	Whitley	1,000	6		-5	Some gas at 300 feet.
	Cumberland	1,700				Small showing of oil and gas.
	Meade	400-765				Gas wells; some brine.
mile	Boyd	2,025	10-6			Gas well.
miles	do	2,322				For oil.
	Harlan	423	2			
	Breckinridge	+896				Several gas wells in vicinity; salt water at 400 feet, strong brine at 600 feet.
	Cumberland	+400				Oil well.
Falls	Whitley	+400				Salt.
	Harrison	1,000-1,300			-8	Several wells.
	Boyle	560	6			Unsuccessful.
w)	Lyon	1,315				Water 200 to 300 feet.
	Fleming	600				For oil.
	Franklin	825	6	Many.	Flows.	
	Barren	1,200				
iles	do	1,370				Several gas wells.
ion (3 st).[11]	do	1,511				Salt water at about 700 feet.
ear).	Lyon	1,315				Oil prospect; abandoned.
gs (6	Grayson	1,000	6	Many.	Flows.	Temp. 61½°.
miles	Greenup	940				Some oil at 400 feet; salt water at 500 feet; abandoned.
s)	do	+1,300				Some oil at 580 feet; abandoned.
miles	Pulaski	1,000				For oil, none found; abandoned.
	do	1,100				Abandoned.
	Whitley	500	2			Coal prospect; some water at 60 feet.
	Mercer	1,500	8		Flows.	Water at 1,100 feet; no gas.
ear).	Jessamine	485	5			Water unfit for use.
	Ohio	1,000				Salt water.
miles	do	+1,300			Flows.	Gas and salt water.
	Hancock	+1,500				Salt water only.
[14]	Perry	+400				Salt well.
	Henderson	+459				Coal prospect.

Geol. Surv. Reports, vol. I[5], pp.

pp. 335–336.
pp. 336–337.
., Petroleum and Natural Gas, rton, pp. 159–160.
82.
77.
72, 176.
93.

[10] Record, ibid., p. 154.
[11] Record, ibid., pp. 155–156.
[12] Ky. Geol. Surv. Report, vol. 1, new series, p. 92.
[13] Ky. Geol. Surv., Petroleum and Natural Gas, etc., by E. Orton, p. 194.
[14] Record, Ky. Geol. Surv. Report, 1854–1855, pp. 36–39.
[15] Ibid., pp. 32–36; Ky. Geol. Surv., Petroleum and Natural Gas, etc., by E. Orton, pp. 195–196.

KENTUCKY—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Henderson [1]	Henderson	+900			Flows.	Brine.
Henderson (near)	do	1,024				Do.
Henderson (16 miles south). [2]	do	430 or 536				Two wells: one yields gas.
Hendricks	Magoffin	2,484	8–5			Some oil: no water below 825 feet.
Hood Creek [3]	Lawrence	1,625				Oil well.
Hopkinsville [4]	Christian	1,600				Some gas and oil at bottom.
Inez	Martin	2,200				
Do	do	950				For oil.
Keene	Jessamine	2,000				For oil 40 years ago.
Lagrange [5]	Oldham	1,500				Flow of salt water at 1,400 feet: no gas.
Do. [5]	do	1,200				Salt water at 1,200 feet: no gas.
Lagrange (1 mile south). [5]		585				Gas well.
Laurel [6]	Lawrence	1,625				Sulphur water at 1,607 feet.
——— [7]	do	1,840–2,597				For oil or gas; unsuccessful.
Leatherwood Creek (mouth). [8]	Perry	410				Salt wells.
Lexington	Fayette	875	6			No water supply.
Louisa (20 miles west) [9]	Lawrence	2,105				For oil or gas; unproductive.
Louisa (9 miles southwest). [10]	do	2,407				Do.
Louisville (Dupont's). [11]	Jefferson	2,088	3	264	+170	Mineral water; temp. 86½° (or 76½°?).
Louisville (Phœnix Brewery).	do	1,800	8	Many.	+ 60	
Louisville (St. Patrick's). [12]	do	1,900		Many.	Flows.	Temp. 57.2°; salt water.
Louisville (Haynes's farm). [13]	do	1,000				Some gas at 400 feet.
Louisville (McGehee farm). [13]		1,000				No product.
Monticello	Wayne	200–700				Oil wells.
Morganfield [14]	Union	525	2			For oil; abandoned.
Morgantown	Butler	500				Oil, gas, and coal.
Newport [15]	Campbell	2,007				Much water at 1,650 feet.
Owensboro [16]	Daviess	1,000	4			Brine at 765 feet; poor water below.
Do	do	1,480				Salt water at 780 feet; none below.
Do	do	1,200				
Owensboro (2 miles east).	do	1,000				But little gas.
Pactolus (near) [17]	Grayson	1,480			−100	For oil or gas: unproductive; much salt water at 1,475 feet.
Paducah [18]	Calloway	1,250				
Panola	Madison	1,700	4			Salt water at 150 and 1,700 feet.
Perryville	Boyle	650	6			For oil; unsuccessful.
Pineville	Bell	650				Oil well.
Smithland [19]	Livingston	1,200				Unsuccessful.
Smithland (Taylor farm).	do	+1,500				

[1] Ky. Geol. Surv., Petroleum and Natural Gas, etc., by E. Orton, p. 195.
[2] Ibid., p. 196.
[3] Record, Pa. 2d Geol. Surv. Reports, vol. I[5], p. 339.
[4] Ky. Geol. Surv., Petroleum and Natural Gas, etc., by E. Orton, pp. 162–165.
[5] Ibid., pp. 167–168.
[6] Record, Geol. Surv. Penn. Report I[5], Oil and Gas Region, p. 339.
[7] Record, ibid., pp. 335–339.
[8] Ky. Geol. Surv. Repts. 1854–1855, p. 228.
[9] Record, Pa. 2d Geol. Surv. Repts., vol. I[5], p. 338.
[10] Record, ibid., pp. 337–338.
[11] Record and analysis, Am. Jour. Sci., 2d series, vol. 27, pp. 174–178.
[12] Ky. Geol. Surv., Petroleum, Natural Gas, etc., by Orton, pp. 169–170.
[13] Ibid., p. 173.
[14] Ibid., p. 205.
[15] Record and analysis, Ohio Geol. Surv. Report 1888, vol. 6, pp. 298–300.
[16] Ky. Geol. Surv., Petroleum, Gas, etc., by Orton, p. 194.
[17] Record, Pa. Geol. Surv. Report I[5] on Oil and Gas Region, p. 340.
[18] Record, Ky. Geol. Surv. Description of Jackson Purchase Region, pp. 321–326.
[19] Ky. Geol. Surv., Petroleum, Gas, etc., by Orton, p. 198.

KENTUCKY—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Uniontown	Union	1,079	4		Flows.	For gas.
Uniontown (Davis mill).	do	+400	5-6		Flows.	Salt water.
Walton	Boone	±400				Gas well.
Warfield (near)[1]	Martin	+1,307				Do.
West Point (vicinity).[2]	Hardin	400				For gas; unsuccessful.
Whitesburg	Letcher	400				Salt wells.
Williamsburg (10 miles above).	Whitley	500	6			For oil; unsuccessful.
Williamstown	Grant	500				No water below 30 feet.

PRINCIPAL PUBLICATIONS RELATING TO DEEP BORINGS IN KENTUCKY.

Seventh Report on Oil and Gas Fields of Western Pennsylvania for 1887–88, by John F. Carll, Pennsylvania Second Geological Survey Reports, volume I, 356 pages, Harrisburg, 1890.

Kentucky Geological Survey Report for 1854–55, by D. D. Owen, Frankfort, 1856.

Occurrence of Petroleum, Natural Gas, and Asphalt in Western Kentucky, by Edward Orton, Kentucky Geological Survey Report, 1888–89, 232 pages, Frankfort.

LOUISIANA.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Aldenbridge	Bossier	400				
Alexandria	Rapides	735	10-6	276½	+4	
Do	do	850				
Do	do	630				Four wells; temp. 85° ±.
Allentown	Bossier	400				
Bosco City	Ouachita	400	6		−30	
Baton Rouge	East Baton Rouge.	1,000	6	243	−30	Water at 750 feet.
Do	do	760	10-6		Flows.	Temp. 70°; two wells.
Bayou Sara	West Feliciana.	736	4	347	+2	Temp. 63°.
Do	do	450			+1	
Benton	Bossier	500				
Bolinger	do	500				
Boyce	Rapides	810		18	+15	Temp. 69°.
Colfax	Grant	1,103	2½	42	+65	Temp. 62°; salty water; much gas.
Cote Blanche Island	St. Mary	450		104	−34	
Crawford	do	692	4	18	+2	Pumps 347 gallons; Temp. 62°; several other wells here.
Crowley	Acadia	635	4	312	−6	Pumps 312 gallons.
Delta	Madison	1,200				No water.
Dubach	Lincoln					Deep well.
Hammond	Tangipahoa	473	5	300	+12	
Lake Charles	Calcasieu	535	6-4	104	+18	Four wells; temp. 64°.
Lake Charles (2 miles east).	do	498	4	100	+10	
Do	do	510	6-4		Flows.	Two wells.
Do	do	500				
Lake City	Jefferson?	1,200				
Marksville	Avoyelles	800				

[1] Record, Pa. Geol. Surv. Report I[5] on Oil and Gas Region, pp. 339-340.
[2] Ky. Geol. Surv., Petroleum, Gas, etc., by Orton, pp. 180-181.

LOUISIANA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Minden	Webster	1,000			No flow.	
New Iberia	Iberia	600				
New Orleans	Orleans	1,200–1,000			+15	Several wells; temp. 68°.
New Orleans (Canal street).	do	3,000				Bored in 1856.
New Orleans	do	1,300				
Winnfield	Winn	1,100	8			Temp. 70°. Also gas.

MAINE.

Augusta	Kennebec	570		10	No flow.	In granite.

MARYLAND.

Arbutus	Baltimore	775				Not finished.
Baltimore (National Brewery).	do	450	6	20	No flow.	
Baltimore (Maltby property).	do	900		Many.	No flow.	
Baltimore (Spring Garden Brewery).	do	500			No flow.	
Baltimore (Hannis Distillery).	do	800			No flow.	
Baltimore (Seawell)	do	562		None.		
Baltimore (Baumschmidt's Brewery)	do	400		25		
Baltimore (Von Der Horst's Brewery).	do	435	8	25	No flow.	
Baltimore (Brehm's Brewery).	do	1,300		120	No flow.	
Baltimore (Adler's Brewery).	do	800				
Bay Ridge	Anne Arundel.	470	6–4	20		Irony water.
Centerville [1]	Queen Anne	665		Many.	Near surface.	Water at 428 and 665 feet.
Claiborne [2]	Talbot	440	6	Many.		Water also at 380 feet.
Cumberland	Allegany	2,000	8	None.		Abandoned.
Crisfield	Somerset	1,018	3	Pumps 200.	Flows.	Flows 40 gallons: saline water.
Do	do	1,033	4	130	Flows.	Saline water.
Do [3]	do	1,080	6		Flows.	Do.
Deer Park	Garrett	2,010	5		Flows.	
Easton	Talbot	600	3	None.		No water below 100 feet.
Elkton	Cecil	490	2½			Water very unsatisfactory; temp. 45°.
Do	do	400				Abandoned.
Do	do	407				Unsuccessful.
Fort Washington						
Frederick	Frederick	1,140–996		70	+3	
Frostburg	Allegany	700	1½	None.		Abandoned.
Indian Head	Charles	463	6	11	No flow.	
Salisbury [4]	Wicomico	424				Water at 267 feet.
Sparrows Point		495				No water below 210 feet.
Tilghmans Island	Talbot	370–420		Many.		4 wells.
Tunis Mills	do	430	2	Pumps 100.	Flows.	Flows 6 gallons.

[1] Record, New Jersey Geol. Surv., Report for 1899, pp. 81–83.
[2] U. S. Geol. Surv., Bull. 138, p. 132.
[3] Record, U. S. Geol. Surv., Bull. 138, pp. 128–130.
[4] Record, New Jersey Geol. Surv., Report for 1899, pp. 113–115.

MASSACHUSETTS.

L	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
n Cold	Suffolk	400	8	70	No flow.	
Hunt- ie and treet).	do	512	8	Few.	No flow.	Bad water.
Com- Prince	do	1,750			No flow.	
rovi-).	do	2,503	7¼		5	Sulphur water; good water 459–484 feet; well abandoned.
quare)	do	2,567				No water below 500 feet.
(Dow).	do	500				Unsuccessful.
Morse reets).	do	462	6			Do.
	do	400				Do.
	Berkshire	+400		Many.	No flow.	
	Suffolk	870–900			No flow.	2 wells; water very salty.
	Hampden	400	8	400	+20	
	do	800	8	600	+20	
	do	720	8	400	−14	
	do	1,005	8	Many.	No flow.	Water too irony.
	Middlesex	650	8	65	No flow.	Water of fair quality.
	Bristol	510	6	2¼	No flow.	
	Berkshire	500	8	625	−4	Very hard water.
	Hampshire	3,710	8	7	No flow.	Not successful.
	do	4,022				Do.
	Worcester	900		Few.		
	Suffolk	502	6		−20	
	do	403				
	Berkshire	650	8			Do.
	Bristol	975	8	52	−12	Water too irony.
	Franklin	900	6		No flow.	Water too hard.
	Norfolk	1,000		15		
	Middlesex	460		Very few.	No flow.	
	do	700		Many.		
gton	Hampshire	625	8	2¼	No flow.	Water too irony.

MICHIGAN.

	Lenawee	1,650				Mineral water at 805 feet. Abandoned.
	Calhoun					Several wells.
	St. Clair	1,614				Salt well.
iles	do	1,727				Do.
	Allegan	1,275–1,400				Several borings for oil; not much found.
	Gratiot	2,893			2	
	Alpena	650	5	200	+20	Temp. 52°. Several wells.
	do	1,026–1,289				Several salt wells.
	Washtenaw	770 or 775			40	
	Barry	1,850				For oil; unsuccessful.
	Calhoun	440			16	Water at 116 feet only.
	Bay	774–980				Salt wells.
	do	715–1,200				Numerous salt wells in vicinity.
	Bay	505				Salt wells in upper salt beds.
	do	1,600				

h. Geol. Surv. Reports, 1881–1893, vol. 5, part 2, p. 44, pl. I.

-45, pl. 4.
id., pp. 45–46; U. S. Geol. Surv. Water Supply and Irrigation Paper, No. 31, p. 83.
h. Geol. Surv. Reports, 1881–1893, vol. 5, part 2, pp. 46–47, pl. 5.
-49; Reports, 1873–1876, vol. 3, part 1, p. 92.
h. Geol. Surv. Reports, 1881–1893, vol. 5, part 2, p. 50.
ich. Geol. Surv. *Reports*, 1873–1876, vol. 3, part 1, p. 182.

MICHIGAN—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Bay City[1]	Bay	2,865				Brine at 2,141–2,706 feet.
Benton Harbor[2]	Berrien	1,205				
Do	do	1,400	10–6	Many.	−30	
Big Rapids	Mecosta	1,300		Many.	−30	Mineral water.
Blackmar	Saginaw	1,764				Salt well.
Carrollton	do	743–800				Several salt wells.
Caswell[3]	Thuron	1,735–1,770				Salt wells.
Chadwick	Ionia	498				
Charlevoix[4]	Charlevoix	400–482	8		Flow.	Temp. 46°.
Charlotte[5]	Eaton	2,200	6		20	
Do	do	730				
Cheboygan[6]	Cheboygan	700				
Do	do	452	10–8		To surface.	
Coldwater (west of)[7]	Branch	447				Water at 223 feet; brine at 282 feet.
Do.[8]	do	1,200				
Constantine[9]	Saint Joseph	680				Strong brine at 382 feet.
Do.[10]	do	+1,080				
Corunna[11]	Shiawassee	907				
Detroit (9 miles northeast).[12]	Wayne	770				Some gas and water at 165 feet.
Dowagiac	Cass	1,500				Unsuccessful.
Do	do	2,200				Water at 87 feet; brine at 387 feet.
Do.[13]	do	1,760				
Do	do	2,300				Water at 90 feet; brine at 780 feet.
East Saginaw[14]	Saginaw	806				Salt well.
East Tawas[15]	Iosco	905				Do.
Essexville[16]	Bay	755				
Flint[17]	Genesee	1,200				Salt well; fresh water at 200 feet.
Florence	Saint Joseph	870				Salt wells.
Forestville	Sanilac	505–600				Abandoned and filled up.
Fountain Point	Carp Lake, Leelanau.		8		+15	
Frankfort[18]	Benzie	1,800				
Do.[19]	do	2,200		100	Flows.	Temperature 58°; mineral water.
Grand Marais	Alger	1,215		None.		Abandoned.
Grand Rapids[20]	Kent	2,200				Fresh water with gas and brine at bottom.
Do	do	(?) 700				
Grindstone	Huron	1,080				Abandoned.
Hillsdale[21]	Hillsdale	1,350–1,550				Brine at 1,100 feet.
Howell	Livingston	550				Gas; abandoned.
Imlay[22]	Lapeer	1,020				Fresh water at 190 to 200 feet; salt water at 648 to 710 feet.
Ionia	Ionia	400–600	8	Many.	+7	No water below 362 feet; temperature 55°.

[1] Record, Mich. Geol. Surv. Reports, 1881–1883, vol. 5, part 2, p. 50, pl. 6.
[2] Ibid., p. 51, pl. 7.
[3] Ibid., p. 53; Mich. Geol. Surv. Reports, 1873–1876, vol. 3, part 1, p. 94.
[4] U. S. Geol. Surv. Water Supply and Irrigation Paper, No. 30, p. 87.
[5] Record, Mich. Geol. Surv. Reports, 1881–1883, vol. 5, part 2, p. 53, pl. 8.
[6] Mich. Geol. Surv. Reports, 1881–1883, vol. 5, part 2, p. 53.
[7] Record, Mich. Geol. Surv. Reports, 1873–1876, vol. 3, part 1, p. 87–88.
[8] Record, Mich. Geol. Surv. Reports, 1881–1883, vol. 5, part 2, p. 54, pl. 10.
[9] Record, Mich. Geol. Surv. Reports, 1873–1876, vol. 3, part 1, p. 93.
[10] Record, Mich. Geol. Surv. Reports, 1881–1883, vol. 5, part 2, p. 54, pl. 11.
[11] Ibid., p. 54, pl. 12.
[12] Ibid., p. 54, pl. 15.
[13] Ibid., p. 55, pl. 16.
[14] Ibid., p. 55; Mich. Geol. Surv. Reports, 1873–1876, vol. 3, part 1, pp. 94–96; Analysis, p. 183.
[15] Record, Mich. Geol. Surv. Reports, 1881–1883, vol. 5, part 2, p. 57; Analysis, Mich. Geol. Surv. Reports, 1873–1876, vol. 3, part 1, p. 184.
[16] Record, Mich. Geol. Surv. Reports, 1881–1883, vol. 5, part 2, p. 58.
[17] Ibid., p. 58; Mich. Geol. Surv. Reports, 1873–1876, vol. 3, part 1, p. 97.
[18] Record, Mich. Geol. Surv. Reports, 1881–1883, vol. 5, part 2, p. 59, pl. 18.
[19] Analysis, ibid., p. 59.
[20] Record, ibid., p. 61, pl. 20.
[21] Ibid., p. 62; Mich. Geol. Surv. Reports, 1883–1876, vol. 3, part 1, p. 81.
[22] Record, Mich. Geol. Surv. Reports, 1881–1883, vol. 5, part 2, p. 63, pl. 22.

MICHIGAN—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Ionia [1]	Ionia	450				Flow of sweet water at 300 feet.
Ithaca [2]	Gratiot	637	8	50	−72	Several wells; good water.
Jackson [3]	Jackson	2,100–2,455			Flows.	Several wells. Flow of water at 1,050 feet; hot water at 1,820 feet.
Do	do	2,700				Abandoned.
Do	do	206–400	10	Many.	−9	Large water supply; several wells.
Kalamazoo [4]	Kalamazoo	2,250				
Kawkawlin [5]	Bay	810–1,133				Two salt wells.
Lake Linden	Houghton	1,502–1,508	12–8	100		
Lansing "magnetic well."	Ingham	1,400		1	Flows.	Saline water. Temperature 58°.
Lansing Hotel	do	740				
Lansing Reform School. [6]	do	506				
Ludington [7]	Mason	2,220				
Do. [8]	do	1,650				
Ludington (1 mile south). [9]	do	2,260				
Manistee [10]	Manistee	1,947–2,027				Numerous salt wells in town and vicinity. Black water at 960. Some oil at 1,905 feet.
Do	do	2,015	10–5		−15	Two salt wells.
Marengo [11]	Calhoun	460				
Marine City [12]	St. Clair	1,470–1,737				Several salt wells in and near town.
Marine City (city well). [13]	do	1,777			Flows.	Clear water 1,170–1,370 feet.
Marshall [14]	Calhoun	440			Flows.	
Maryville [15]	St. Clair	1,150				Salt water at 745 feet; mineral water 970 and 985 feet.
Melbourne	Saginaw	950				
Menominee	Menominee	+400				
Midland [16]	Midland	1,300–1,325				
Monroe [17]	Monroe	1,765	8	Several.	+ 4	Well now plugged; water somewhat sulphurous.
Mount Clemens [18]	Macomb	1,060–1,244				Several mineral wells.
Muskegon [19]	Muskegon	1,230				Flows of mineral water at 333 feet and 643 feet.
Do. [20]	do	2,627				Strong flow of mineral water at 700 feet, brine at 2,400 feet.
New River [21]		1,029				Salt well.
Niles	Berrien	1,438	10–5	15	+15	Temperature 60°.
Do. [22]	do	1,140				

[1] Record, Mich. Geol. Surv. Reports, 1873–1876, vol. 3, part 1, pp. 134–135.
[2] Record, Mich. Geol. Surv. Reports, 1881–1893, vol. 5, part 2, pp. 63–64.
[3] Ibid., p. 65, pls. 23–25.
[4] Record, Mich. Geol. Surv. Reports, 1881–1893, vol. 5, part 2, p. 65, pl. 26.
[5] Ibid., p. 65; Mich. Geol. Surv. Reports, 1873–1876, vol. 3, part 1, p. 96.
[6] Record, Mich. Geol. Surv. Reports, 1873–1876, vol. 3, part 1, pp. 117–118.
[7] Record, Mich. Geol. Surv. Reports, 1881–1893, vol. 5, part 2, p. 66, pl. 27.
[8] Ibid., pl. 29.
[9] Ibid., pl. 28.
[10] Ibid., p. 66, pls. 30–32.
[11] Ibid., p. 67.
[12] Ibid., p. 67, pls. 33–38.
[13] Ibid., p. 67, pl. 39.
[14] Ibid., p. 67.
[15] Ibid., p. 68, pl. 40.
[16] Record, Mich. Geol. Surv. Reports, 1881–1893, vol. 5, part 2, p. 69.
[17] Ibid., p. 70, pl. 41.
[18] Record, and analysis, ibid., pp. 70–71, pl. 42.
[19] Record, ibid., p. 71, pl. 43; Mich. Geol. Surv. Reports, 1873–1876, vol. 3, part 1, p. 84.
[20] Ibid., p. 85.
[21] Ibid., p. 77; Mich. Geol. Surv. Reports, 1881–1893, vol. 5, part 2, p. 73.
[22] Record, Mich. Geol. Surv. Reports, 1881–1893, part 2, p. 73, pl. 44.

MICHIGAN—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Niles[1]	Berrien	600				Strong brine at 370 feet.
Norris	Wayne	631				For gas; abandoned.
Oscoda[2]	Iosco	1,070-1,103				Salt wells.
Owosso[3]	Shiawassee	1,000				Brine at 634 feet.
Petoskey	Emmet	575	10-8	450	+18	Temperature 50°.
Pontiac[4]	Oakland	1,505				Salt water at 1,109 feet.
Port Austin[5]	Huron	1,198-1,225				Salt wells; sweet water at 336 to 1,160 feet.
Port Hope[6]	do	787				Salt well.
Port Huron[7]	St. Clair	498-785				Gas wells.
Port Huron (12 miles northwest).	do				Flows.	
Port Huron[8]	do	1,700				Gas and salt.
Port Huron Deerspring.	do	745			-150	Slightly mineral water.
Portsmouth	Bay	1,000				
Do.[9]	do	664				Salt well.
Provemont	Leelanau	700	8		+10	Sulphur water 300 feet in rock.
Romeo[10]	Macomb	1,000			-600	
Royal Oak[11]	Oakland	1,400				
Do.[12]	do	2,502				
Saginaw	Saginaw	741-830				Numerous salt wells.
Do.[13]	do	860				
Saginaw (southeast).[14]	do	1,764				Brine at 350 and 1,655 feet.
St. Clair[15]	St. Clair	919				Salt wells.
Do.[16]	do	1,682			-300	Salt well.
St. Ignace[17]	Mackinac	919	8	Many.	Flows.	Strong sulphur water.
St. Johns	Clinton	1,200				Unsuccessful.
St. Louis	Gratiot					Deep well.
Salsburg	Bay	1,000-1,013				Several salt wells.
Sandbeach[18]	Huron	702				Salt well.
Do.[19]	do	1,920				For gas; unsuccessful.
Stronach[20]	Manistee	1,072				
Tawas City[21]	Iosco	905				Salt well.
Thunder Bay River (near bed).[22]		1,025				Salt well. Flow of mineral water at 400 feet.
Whiterock[23]	Huron	555-1,311				Several salt wells.
Winona	Bay	1,020				Drill hole for copper ore.
Wyandotte[24]	Wayne	2,500				Abandoned.
Do	do	600-800				Numerous salt wells.
Ypsilanti	Washtenaw	808				
Zilwaikee[25]	Saginaw	800-860				Several wells.

[1] Record, Mich. Geol. Surv. Reports, 1873-1876, vol. 3, part 1, p. 93.
[2] Analysis, ibid., p. 186.
[3] Record, ibid., p. 97; Mich. Geol. Surv. Reports, 1881-1893, vol. 5, part 2, p. 78, pl. 45.
[4] Record, Mich. Geol. Surv. Reports, 1881-1893, vol. 5, part 2, p. 75, pl. 47.
[5] Ibid., pp. 75-76; Mich. Geol. Surv. Reports, 1873-1876, vol. 3, part 1, pp. 77-78; Analysis, p. 183.
[6] Ibid., p. 76.
[7] Ibid., p. 77, pls. 48-55.
[8] Ibid., pp. 77, pl. 57.
[9] Analysis, Mich. Geol. Surv. Reports, 1873-1876, vol. 3, part 1, p. 182.
[10] Record, Mich. Geol. Surv. Reports, 1881-1893, vol. 5, part 2, p. 78, pl. 59.
[11] Ibid., p. 79.
[12] Ibid., p. 79, pl. 60.
[13] Ibid., p. 79; Analysis, Mich. Geol. Surv. Reports, 1873-1876, vol. 3, part 1, p. 182.
[14] Record, Mich. Geol. Surv. Reports, 1873-1876, vol. 3, part 1, pp. 96-97.
[15] Record, Mich. Geol. Surv. Reports, 1881-1893, vol. 5, part 2, p. 79, pl. 62.
[16] Ibid., pl. 61.
[17] Record, Mich. Geol. Surv. Reports, 1881-1893, vol. 5, part 2, p. 79, pl. 63.
[18] Analysis, Mich. Geol. Surv. Reports, 1873-1876, vol. 3, part 1, p. 184.
[19] Record, Mich. Geol. Surv. Reports, 1881-1893, vol. 5, part 2, pp. 81-82.
[20] Record, ibid., p. 84, pl. 65.
[21] Record, Mich. Geol. Surv. Reports, 1873-1876, vol. 3, part 1, p. 79.
[22] Mich. Geol. Surv. Reports, 1873-1876, vol. 3, part 1, p. 40.
[23] Ibid., pp. 76-77; Analysis, p. 184; Record, Mich. Geol. Surv. Reports, 1881-1893, vol. 5, part 2, p. 86.
[24] Record, Mich. Geol. Surv. Reports, 1881-1893, vol. 5, part 2, p. 87, pl. 66.
[25] Analysis, Mich. Geol. Surv. Reports, 1873-1876, vol. 3, part 1, p. 185.

LICATIONS RELATING TO DEEP BORINGS IN MICHIGAN.

eology of Lower Peninsular of Michigan, by C. Rominger, Michigan Geo-urvey, vol. 3, part 1, 225 pages, New York, 1876.

eology of Lower Michigan with reference to deep borings, etc., by A. C. ichigan Geological Survey, Vol. 5, part 2, 100 pages, plates, Lansing, 1895.

is of many of the well waters are in "Lower Michigan Mineral Waters," Lane, U. S. Geological Survey, Water-Supply and Irrigation Papers, No. ington, 1899.

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MINNESOTA.

tion.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
.....	Mower	750	10–8	220	−6	Fine water from 600 feet.
ne	Scott	710	.....	.....	.....	
.....	Swift	478	.....	.....	.....	
h	Faribault	1,300	.....	.....	−30	
.....	.....do	1,240	.....	Many.	−30	
				5	×200	First flow at 420 feet; second flow at 425 feet.
alley[1]	Traverse ..	465	.....			
le[2]	Houston	590	.....	1,000	+13	
ıter	Dodge	504	8	80	−88	Railroad well.
12 miles	St. Louis	1,507	8–5	.....	−40	Mineral water at 1,225 feet.
ıeapolis[4]...	Hennepin	1,421	.....	.....	.....	
.....	Sherburne...	513	.....	Many.	+4	Several wells in vicinity; only flow is at 308 feet.
.....	Rice	520	.....	.....	.....	Signs of gas.
ıac	St. Louis.....	1,508	.....	.....	−10±	Salty water; bored for gas.
.....	Fillmore	579	6	20	−225	
.....	Freeborn	950	.....	.....	.....	Unsuccessful.
.....	Ramsey	615	.....	.....	−30	
.....	McLeod	1,640	8–6	50	−85	
.....	.....do	1,000	.....	50	.....	
.....	Bigstone	480	8–6	40	−50	Two wells; granite at 510 feet.
y	Meeker	700	.....	.....	−57	
.....	Dakota.....	1,160	.....	100	+14	Water slightly salty.
.....	.....	530	.....	None.	.....	
ı	Sibley.....	707	10–8	400	+70	Temp. 50°.
.....	Kittson	644	.....	.....	.....	Salty water at 170–180 feet.
.....	Scott.....	650?	.....	.....	.....	
.....	Kandiyohi...	450	.....	.....	.....	Unsuccessful.
.....	Wabasha....	820	.....	.....	.....	
n	Redwood	400	.....	.....	.....	
.....	Blue Earth ..	2,204	.....	.....	−90	Unsuccessful.
.....	....do	650	10, 8, 6	500 to 80	+40	Several wells. Water ferruginous.
.....	.....	857	4	10	+10	
lis.....	Hennepin	1,431	.....	.....	.....	Several wells unsuccessful.
lis (Lake-metery)[9]	.....do	2,150	.....	.....	.....	
lis (West [9]	.....do	622	.....	300	−24	Water at 168 feet.
lis (C. M. P. R. R.	....do	.....	.....	.....	.....	

d, Minn. Geol. Surv., 14th Rept., 1885, p. 14. Report Special Comm. U. S. Senate on Irrigation eclamation of Arid Lands, vol. 4, Washington, 1890, p. 48.
d, Minn. Geol. Surv., 13th Rept., 1884, p. 59. Report Special Comm. U. S. Senate on Irrigation eclamation of Arid Lands, vol. 4, Washington, 1890, p. 48; Minn. Acad. Natural Sciences 3, No. 1, p. 142.
d, Minn. Geol. Surv. Bull. 5, Gas in Minnesota, pp. 31–35.
d, Minn. Geol. Surv. Report, vol. 5, 1876, pp. 154–156.
d, Minn. Geol. Surv., 13th Rept., 1884, pp. 56–57; Analysis and Record Minn. Acad. of ciences Bull., vol. 3, No. 1, pp. 137–141.
d and analysis, Minn. Geol. Surv., 13th Rept., 1884, pp. 42–47.
d, ibid., p. 58; Minn. Acad. Natural Sciences Bull., vol. 3, No. 1, p. 142.
d, Minn. Acad. Natural Sciences Bull., vol. 3, No. 1, p. 141; Minn. Geol. Surv., 13th Rept., 1, 56.
pp. 137–138; ibid., pp. 50–54.
sis, *ibid., p. 137; Record, Minn.* Geol. Surv., 14th Rept., 1885, p. 11.

MINNESOTA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Minneapolis (Soldiers' Home).	Hennepin					
Minneapolis (Winslow House.	do	1,421			No flow.	Abandoned.
Minneopa Falls[1]	Blue Earth	1,000	8–6			Flow at 540 feet, and salty water at 900 feet; granite at 980 feet.
Monticello	Wright	500			−18	Good water.
Moorhead[2]	Clay	1,901				Water at 120, 125, and 370 feet.
Do.[3]	do	1,425				Water at 120 feet and 1,425 feet.
New Germany	Carver	410	3			Water at 100 feet only.
Northfield	Rice	647	8	1,000	+25	Hard water. Supply is from 300 feet.
Owatonna	Steele	640	8	250	− 8	
Pine City		700	12–4½	75	−70	
Pipestone	Pipestone	537				
Plainview	Wabasha	690	12	100		
Redwing[4]	Goodhue	500	6	100	+75	Flows from 180-450 feet.
St. Charles	Winona	944			−60	
St. James	Watonwan	501	10–8	300	−27	Hard water.
St. Paul (G. N. R. R.)	Ramsey	834			−38	
St. Paul (Elevator Co.).[5]	do	850			−35	
St. Paul (St. P. & D. R. R.)	do	750				
St. Paul Transfer Railroad.	do	575				
St. Paul (West. M. and N. W. R. R.).	do	1,050			−24	
St. Paul city well	do	1,005				
St. Paul (harvester works).[6]	do	871½				
St. Paul, Wilgus well	do	625				
St. Paul Fair Grounds	do	500				
St. Paul, Lake Vadu-ais.	do	726½			−11	
St. Paul, White Bear Lake.	do	777			−18	
St. Vincent (2 miles northwest).[7]	Kittson	1,037				
Scott	Stevens	+400				No water.
South St. Paul	Ramsey	487			5	
Do	do	3,000				For gas.
Stephen	Marshall					No success.
Stillwater[8]	Washington	3,500	5			For gas, unsuccessful: water at 162 and 300 feet; some salt water at 1,950 feet and some gas at 2,250 feet.
Tower (2 miles east).	St. Louis	400	1½	Many.		Diagonal drill hole in gneiss.
Tracy[9]	Lyon	724			− 37	
Do	do	597			−148	
Tyler	Lincoln	+400				
Do	do	+600				
Walnut Grove	Redwood	400				
Waseca	Waseca	1,157	10–8	200	−120	
White Bear	Ramsey[7]	777			−15	
Winona	Winona	478	6	500	+10	Temp. 54°; cased 175 feet.
Worthington	Nobles	600				Unsuccessful.
Wyoming	Chicago	505	8–6	Many.	−13	

[1] Record, Minn. Geol. Surv. Bull. 5, Gas in Minnesota, pp. 23-24.
[2] Report on Irrigation, 52d Congress, 1st session, Senate Ex. Doc. No. 41, part 2, pp. 72-74, Washington, 1893.
[3] Record, Report of Special Comm. U. S. Senate on Irrigation and Reclamation of Arid Lands, vol. 4, p. 48, Washington, 1890; Minn. Geol. Surv. Bull. 5, Gas in Minnesota, pp. 27-31.
[4] Record Minn. Acad. Natural Sciences Bull., vol. 3, No. 1, p. 42; Minn. Geol. Surv., 13th Report, 1884, pp. 57-58.
[5] Record, Minn. Geol. Surv., 13th Rept., 1884, p. 63; Minn. Acad. Natural Sciences Bull., vol. 3, No. 1, p. 140.
[6] Ibid., pp. 59-63; ibid., p. 140.
[7] Record, Minn. Geol. Surv., 14th Rept., 1885, p. 15.
[8] Record, Minn. Geol. Surv. Bull. 5, Gas in Minnesota, pp. 25-27; Am. Geologist, vol. 3, p. 343.
[9] *Record. Minn. Geol. Surv.*, 14th Rept., 1885, pp. 351-352.

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ota Geological Survey, Thirteenth Annual Report, for 1884, by N. H. , 196 pages, plates, St. Paul, 1884.
ota Geological Survey, Fourteenth Annual Report, for 1885, part 1, by nchell, 165 pages, St. Paul, 1886.
ota Academy of Natural Sciences Bulletin, Vol. III, No. 1, Proceedings mpanying Papers, 1883–1886, by C. W. Hall, 160 pages, plates, Minne- 89.
ota Geological Survey Bulletin No. 5, Natural Gas in Minnesota, by N. ıell, 39 pages, St. Paul, 1889.
of the Special Committee of the United States Senate on the Irrigation amation of Arid Lands, vol. 4, 386 pages, Washington, 1890.

MISSISSIPPI.

tion.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
4½ miles	Lowndes	700	4–3	10	−90	
uis	Hancock	400–760	4½–2	100–5	Flow.	Many wells. Temperature of deeper wells 78°.
	Harrison	850				
lley	Noxubee	±500			Flow.	
	Perry	650			−30	
	Noxubee	680		10	−75	
	Madison	1,021	8–3	90	+10	Temp. 74°.
e	Noxubee	±500			Flow.	Three wells.
	Lowndes	400		Each 80	Flow.	Two wells; temperature 70°.
	Jones	1,160	3			No water below 650 feet.
	Scott	520			−90	Water at 220 feet, court-house well.
d	Leflore	400			+40	Three wells.
	do	506	6	400	−45	
	do	400			+40	Twenty wells in adjoining region.
	Harrison	700	4½–2	80	+25	Temp. 71° +.
	Chickasaw	1,500	3	Few.	−50	
	Sunflower	800				Unsuccessful.
	Hinds	1,200		Many.		
	do	604		Many.		
	Oktibbeha	936	10	25	−5	
	Sunflower	950	3		+50	
burg	Yazoo	620			−40	
	Noxubee	763			Flows.	Two wells.
	Chickasaw	600			−65	
ck	Noxubee	±600			Flows.	Several wells.
	do	700		10	−25	
	Tippah	600	10–8		−25	
	Madison	720			−20	
	Yazoo	588	3	15	+4	
	Jackson	774	6	700	+45	Temp. 74°.
	do	750	3		Flows.	
	do	780	6			
	do	727	2			
	Holmes	800			Flows.	Two wells.
	do	456	2		+16	
	do	470			Flows.	
	Warren	1,000		Few.	Flows.	
	Copiah	1,300				Unsuccessful.
	do	1,400				
r	Yazoo	635			+20	
	do	500	3		−140	
	do	475	4	40	+5	Two wells.
	do	740				
	do	800				
	do	1,254				
y (18 miles st).	do	588			−130	
y (25 miles st).	do	588	2	14	+12	Temp. 70°.
y (4 miles	do	696	2		+9	

MISSOURI.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Annapolis (near)		663–400				Several prosp holes.
Bartlett	Shannon	+400				
Do	do	740	6	70	−340	
Baryties	Washington	495				Abandoned.
Bethany	Harrison	654	3¼	5	Flows.	Temp. 47°.
Bethel (4 miles north)	Shelby	450	6	1	−90	
Birchtree	Shannon	+400				
Boonslick[1]	Howard	1,008	3	Many.		
Booneville	Cooper	403	6		−78	Water strongly eral; abandon
Brookfield	Linn	451		30	−200	
Brunswick[2]	Chariton	1,505	6–4	7	Flows.	Mineral water.
Chillicothe	Livingston	700				No water.
Do	do	539		Many.	−90	
Do	do	481		2	Flows.	
Clayton	St. Louis	1,000				
Clinton	Henry	650	8	200	+20	
Do	do	850	8	175	+20	
Do	do	900	10	400	+20	
Do	do	900	6	125	+20	
Do.[3]	do	800	8–5¼	400	+10	Water also at 31 425 feet.
Do.[4]	do	913		2,700		Temp. 64°.
Concordia	Lafayette	+200				In progress.
Diamond	Newton					
Eldorado Springs	Cedar	1,400	8		−28	Sulphur water.
Epworth	Shelby	410		1	−80	
Farmington (near)	St. Francois	442,650	2¼			Prospect borin lead.
Fulton	Calloway	750	8	30	−70	
Galbraith Spring[5]	McDonald	804		Many.		
Granby (sec. 6)	Newton	876	8	600	−40	
Higginsville	Lafayette	1,512	12–5	30	−80	
Jackson	Cape Girardeau.	531	4¼	Many.	−3	Sulphur water in use.
Jefferson City	Cole	1,365				
Joplin		1,375	6	30	−80	Ferruginous w
Kansas City[6]	Jackson	1,000–425			−30	Several test b for gas. W from 380–390 590 feet, an feet. Brackis sulphur wat
Lagrange[7]	Lewis	840		60		Brackish.
Lamar	Barton	1,000	6	Many.	−150	Good water. doned.
Do	do	+2,000				
Lanahan	McDonald	1,428	6	50	Flows.	Sulphur water
Lebanon[8]	Laclede	1,002	8	1	−200	Water at 135 a feet.
Do	do	453	6¼	35		Water at 380 a feet.
Lisle	Jackson	405				No water.
Lonetree		1,000				
Louisiana[9]	Pike	1,275		Many.	Flows.	Temp. 64.2°.
Mexico	Audrain	588	8	10	−100	
Do	do	1,125	8	70		
Do	do	1,100	5¼		−80	
Do	do	+1,800				For oil or g successful. water.
Mine Lamotte	Madison	670	2	4	Flows.	
Moberly		510	8	300	−200	Two wells.
Montgomery City	Montgomery	1,500	10–5¼		−30	
Do	do	600	6	70		Temp. 58°.
Mountainview	Howell	645	6		−500	
Nevada	Vernon	880	10	500	−80	
Do	do	1,001	8	700	−80	Flows to +9 when not pu

[1] Analysis, Mo. Geol. Surv., vol. 3, p. 71.
[2] Analysis, Ibid., pp. 96–97.
[3] Analysis, Mo. Geol. Surv. Reports, vol. 3, pp. 85–87, 118–119.
[4] Analysis, Ibid., pp. 120–121.
[5] Analysis, Mo. Geol. Surv. Reports, vol. 3, pp. 117–118.
[6] Analysis, U. S. Geol. Surv., 17th report, 1895–96, part 2, p. 827.
[7] Analysis, Mo. Geol. Surv. Reports, vol. 3, pp. 141–143.
[8] Record, Geology of Missouri, by Broadhead, part 2, p. 86.
[9] Record and analysis, Ibid., pp. 94–95.

MISSOURI—Continued.

ıcation.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
'	Vernon	800	.....	165	Flows.	
.....	Shelby	+400	.....	.....	.....	
.....	St. Clair	500	7¼	.....	−20	Several water horizons.
phia	Marion	470, 558	.....	300	−6	Two wells; much water; little oil.
luff	Butler	600	8–6	.....	−10	
.....	Washington .	522–585	2	.....	−66	Three wells.
.....	.....do	414	.....	.....	−2	
ı miles north)	Newton	1,244	9	.....	−80	
h Springs[2] ..	Randolph	969	4	120	Flows.	Temp. 58°; mineral water.
t	Atchison	678	8–6	.....	−16	Prospect hole for coal; water at 143 feet.
les	St. Charles...	1,276	6	40	−40	
les (2 miles	.....do	1,365	.....	.....	.....	
evieve	Ste. Genevieve.	700–800	.....	.....	.....	For oil or gas; unsuccessful.
h	Buchanan....	1,000	6	.....	.....	Prospect for coal.
.....	....do	1,300	6	.....	.....	Do.
.....	.....do	1,805	6	.....	.....	Temp. 82°; water mineral.
ph (5 miles	.....do	500	6	Few.	.....	
ı	St. Louis	400–700	.....	30	−200	Many wells.
ı (asylum)...	.....do	3,843¼	.....	Few.	.....	Temp. 105°; salty water.
ı (Belcher)[3] .	.....do	2,176	.....	1	.....	3 per cent salt at 1,231 feet; temp. 66°.
.....	....do	2,199	9–3¼	75	Flows.	Temp. 73.4°; water from 1,515 feet.
....	.....do	+1,590	6–3¼	.....	.....	Gas at 466 feet; salt water at 520 feet; temp. 69° at 1,351 feet.
ıis (power	.....do	1,474	.....	.....	−70	
ain of Rocks.	.....do	735	6	70	−45	Water slightly sulphurous.
(2 miles	Pettis	1,500	9–6	.....	.....	Prospect hole; full of water.
ıld	Greene	755	6	750	.....	Water at 610–620 feet.
airie	Maries	.....	.....	.....	.....	
(5 miles	Crawford	1,200	.....	.....	To surface.	Water also at 20, 240, and 800 feet.
.....	Mercer	+400	.....	.....	.....	
ll	Warren	+400	.....	.....	.....	
lle	Putnam	700	.....	.....	.....	Some water at 215 feet; abandoned.
ton	Warren	450	6–4	1	150	Three wells.
ity	Jasper	500	7¼	.....	−20	Several water horizons.
ins	Howell	575	10	100	−40	
.....	Shannon	700	8, 4–3	Many.	−400	Two wells.
City	Warren	406	6	.....	−70	Fine water.

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rt on the Mineral Waters of Missouri, by Paul Schweitzer, Missouri Geo-Survey, 1890–1892, Vol. III, 256 pages. Jefferson City, 1892.

[1] Analysis, Mo. Geol. Surv. Reports, vol. 3, pp. 121-122.
[2] Analysis, Ibid., pp. 73–74.
[3] Analysis, Mo. Geol. Surv. Reports, vol. 3, pp. 79–81.
[4] Analysis and record, St. Louis Acad. Science, Trans., vol. 1, pp. 80–86, pl. 5.
[5] Record, Am. Jour. Science, 2d series, vol. 15, pp. 460–461.

MONTANA.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Billings	Yellowstone	1,000	.....	.....	.....	All in shale.
Bozeman	Gallatin	400	.....	.....	.....	Bored for oil; unsuccessful.
Chinook[1]	Choteau	956	.....	.....	−50	Waters also at 220, 540, and [illegible]
Fort Assiniboine	do	1,950	.....	.....	.....	Small flow of gas; water below all clay.
Fort Keogh	Custer	811	.....	15	Flows.	
Glendive (court-house).	Montana	500	.....	.....	.....	Unsuccessful.
Helena	Lewis and Clarke.	1,002	.....	.....	.....	
Do	do	1,023	.....	.....	.....	Good flow; abandoned.
Do	do	900	.....	.....	−100	
Junction	Yellowstone	500	.....	.....	Flows.	Small flow also at feet.
Miles City	Custer	472	4-2	.....	Flows.	
Do	do	481	4-2	.....	Flows.	
Do	do	456	4-2	.....	Flows.	
Miles City (court-house).	do	500	4-2	.....	Flows.	
Miles City[2]	do	456	.....	5	−16	Temp. 57°.
Do	do	535	4	2	.....	
Miles City 35 miles west.	do	420	4 2	.....	Flows.	
Miles City	do	452–514	.....	.....	Flow.	5 wells.
Do	do	479	9 2	.....	Flow.	
Miles City 10 miles east.	do	533	.....	.....	Flows.	
Miles City Reform School.	do	507	.....	.....	Flows.	
Rosebud	do	485–502	4 2	.....	Flows.	3 wells.

[1] Report on Irrigation, 52d Cong., 1st sess., Senate Ex. Doc. 41, part 2, pp. 72–73. Washington, 1
[2] Record, Report on Irrigation, 52d Cong., 1st sess., Senate Ex. Doc. No. 41, part 2, pp. 9
Washington, 1893.

[Continued in Water-Supply Paper No. 61.]

1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Big Horn Range and Big Horn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett; and "Preliminary report on the artesian waters of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 280 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, New York, to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 336 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton; and "Reservoirs for irrigation," by J. D. Schuyler.

1898.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1899; octavo, 811 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton; and "A preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

Part II of the Nineteenth Annual contains a paper on "Principles and conditions of the movements of ground water," by F. H. King, and one on "Theoretical investigation of the motion of ground waters," by C. S. Slichter.

1900.

Twentieth Annual Report of the United States Geological Survey, 1898–99, Part IV, Hydrography, 1900; octavo, 660 pp.

Contains a "Report of progress of stream measurements for the calendar year 1899," by F. H. Newell, and "Hydrography of Nicaragua," by A. P. Davis.

1901.

Twenty-first Annual Report of the United States Geological Survey, 1899–1900, Part IV, Hydrography, 1901; octavo, 765 pp.

Contains a "Report of progress of stream measurements for the calendar year 1900," by F. H. Newell; "Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming," by N. H. Darton; and "The High Plains and their utilization," by W. D. Johnson.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Postage stamps, checks, and drafts can not be accepted. Correspondence relating to the publications of the survey should be addressed to

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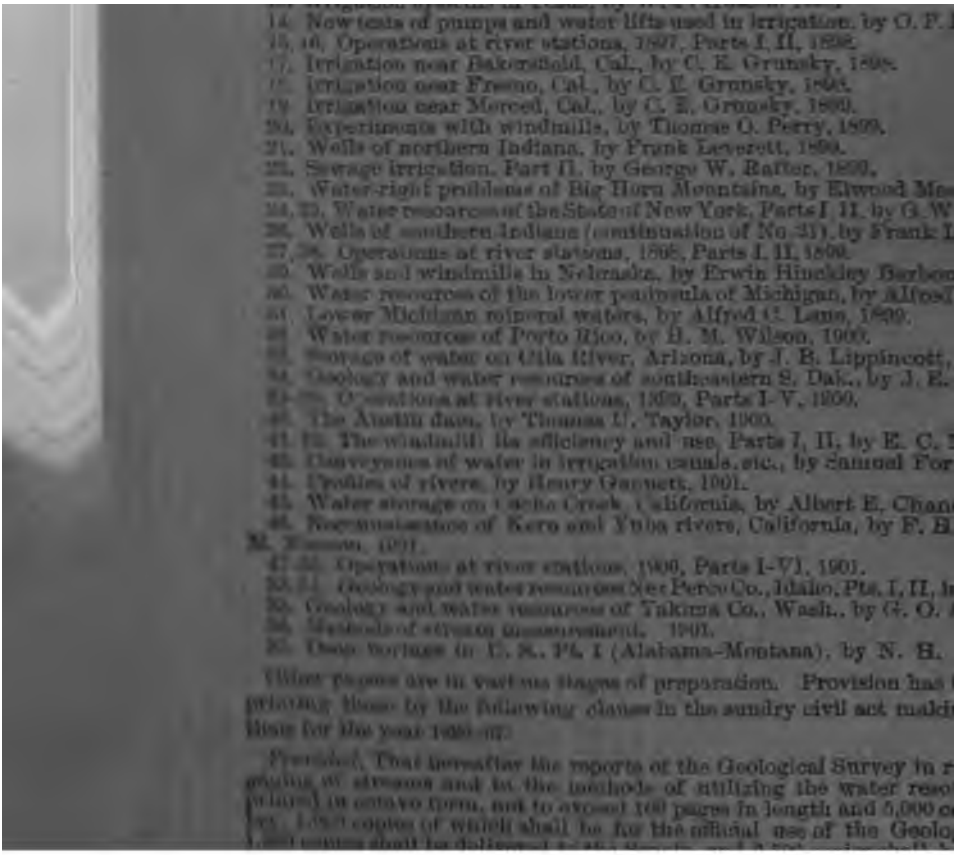

14. Now tests of pumps and water lifts used in irrigation, by O. P.
15, 16. Operations at river stations, 1897, Parts I, II, 1898.
17. Irrigation near Bakersfield, Cal., by C. E. Grunsky, 1898.
18. Irrigation near Fresno, Cal., by C. E. Grunsky, 1898.
19. Irrigation near Merced, Cal., by C. E. Grunsky, 1898.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation. Part II, by George W. Rafter, 1899.
23. Water-right problems of Big Horn Mountains, by Elwood Me
24, 25. Water resources of the State of New York, Parts I, II, by G. W
26. Wells of southern Indiana (continuation of No. 21), by Frank L
27, 28. Operations at river stations, 1898, Parts I, II, 1899.
29. Wells and windmills in Nebraska, by Erwin Hinckley Barbo
30. Water resources of the lower peninsula of Michigan, by Alfred
31. Lower Michigan mineral waters, by Alfred C. Lane, 1899.
32. Water resources of Porto Rico, by H. M. Wilson, 1900.
33. Storage of water on Gila River, Arizona, by J. B. Lippincott,
34. Geology and water resources of southeastern S. Dak., by J. E.
35-39. Operations at river stations, 1899, Parts I-V, 1900.
40. The Austin dam, by Thomas U. Taylor, 1900.
41, 42. The windmill: its efficiency and use, Parts I, II, by E. C.
43. Conveyance of water in irrigation canals, etc., by Samuel Fo
44. Profiles of rivers, by Henry Gannett, 1901.
45. Water storage on Cache Creek, California, by Albert E. Chan
46. Reconnaissance of Kern and Yuba rivers, California, by F. H
M. Rawson, 1901.
47-52. Operations at river stations, 1900, Parts I-VI, 1901.
53-54. Geology and water resources of Lewis and Clarke Counties, Idaho, Pts. I, II, b
55. Geology and water resources of Yakima Co., Wash., by G. O.
56. Methods of stream measurement. 1901.
57. Deep borings in U. S., Pt. I (Alabama–Montana), by N. H.

Other papers are in various stages of preparation. Provision has
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DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

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IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 58

STORAGE OF WATER ON KINGS RIVER, CALIFORNIA—LIPPINCOTT

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

STORAGE OF WATER

ON

KINGS RIVER, CALIFORNIA

BY

JOSEPH BARLOW LIPPINCOTT

WASHINGTON

GOVERNMENT PRINTING OFFICE

1902

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., June 29, 1901.

ve the honor to transmit herewith a manuscript prepared
. Lippincott, giving the results of surveys and investiga-
ter storage and power development on Kings River, Cali-
is investigation was begun as part of the general plan for
g the water resources of the country and the extent to
rid Lands could be redeemed by irrigation.

to assist this work and make it more complete the Cali-
er and Forest Association, organized to promote the irriga-
pments of the State, placed at the disposal of the Geological
sum of $1,000, which had been raised by private subscrip-
ldition to this a local organization known as the Kings
ge Association, cooperating with the other body, increased
by $1,500, to be used for field expenses.

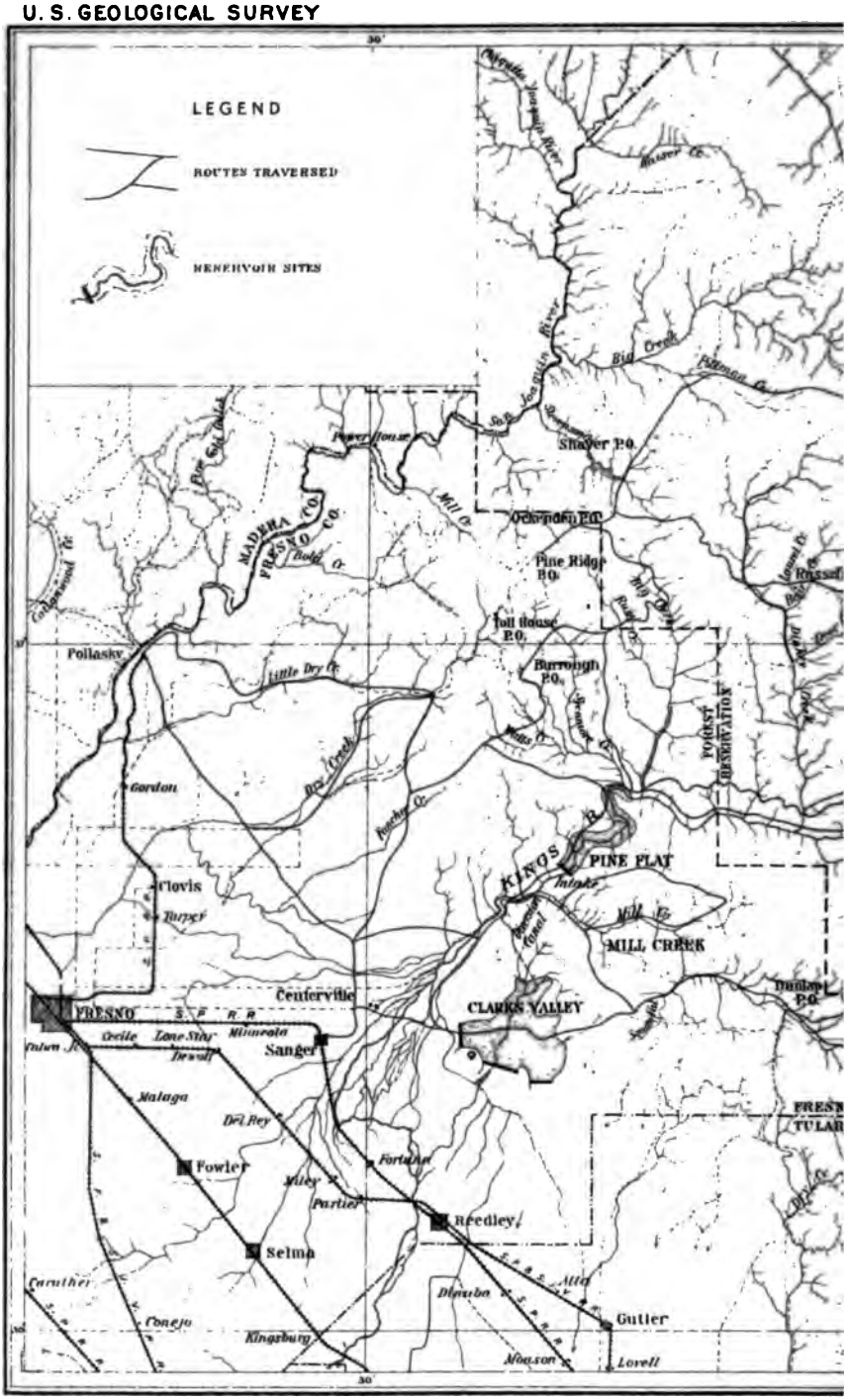
ork the drainage basin of Kings River has been explored
inary surveys and estimates prepared sufficient to justify
ents that works can or can not be economically con-
certain localities. It is not the object of this investigation
ished working plans or final surveys upon which speci-
contracts could be made, that detail being left to those
ave in charge the actual construction of the works. It is
owever, that the estimates are sufficiently broad and con-
enable general conclusions to be drawn. It is understood
ficers of this Survey have no concern with the question
ch works are to be built by private capital or by public
object being to ascertain the important physical features.
tion on Kings River is to a certain extent typical of that
nber of important streams of the West, and as a result of
gation it is believed that the reclaimable area can be greatly
y the construction of storage works and also of power
eans of which, through electrical transmission, pumps can
at small expense out on the broad valleys. The demon-
these conditions will prove one of the most important steps
transformation and utilization of the fertile but arid lands.

respectfully,

F. H. NEWELL,
Hydrographer in Charge.

RLES D. WALCOTT,
rector United States Geological Survey.

U. S. GEOLOGICAL SURVEY



MAP OF DRAINAGE BASIN OF KINGS RIVER, CALIF

Owens River
Silver Canyon
Mill Creek
Bishop
Bishop Creek
High Pk.
FOREST RESERVATION
Main Crest of Sierra
Mt. Abbott
Mt. Gabb
Mt. Hilgard
Seven Gables
Mt. Humphrey
Lake Valley
North Branch
BLANEY MEADOWS
Mt. Henry
Middle Branch
Mt. Darwin
Mt. Haeckel
Mt. Goddard
Agassiz Needle
Mt. Jordan
Mt. Sill
Middle Fork Rush Creek
Owens River
Station
Baker Creek
Big Pine
Big Pine Cr.
Coyote Valley
INYO CO.
FRESNO CO.
Tinemaha P.O.
Tinemaha Cr.
Palisade Creek
Mt. Woodworth
Split Mt.
DUSY MEADOWS
SIMPSON MEADOWS
COLLINS MEADOW
GARLIC MEADOWS
Red Mt.
Arrow Pk.
Goat Mt.
Mt. King
Onion Cr.
Junction
South Fork
LEWIS CREEK
Kings River
Canyon
LONE MEADOW
BUCKEYE FERRY MEADOW
Avalanche Pk.
Bubbs Creek
CHARLOTTE LAKE
BULLFROG LAKE
University Pk.
Simmons Cr.
Lookout Mt.
FRESNO CO.
TULARE CO.
EAST LAKE
Mt. Stanford
Mt. Keith
Junction Pk.
REFLECTION LAKE
Mt. Brewer
Shepherd Cr.
UNSURVEYED
SEQUOIA NATIONAL PARK
Mt. Silliman
Table Mt.
Milestone Mt.
Mt. Tyndall
Mt. Williamson
Mt. Barnard
Tunabora
Mt. Whitney
Panther Pk.
Giant Forest
Middle Fork Kaweah River
Kaweah Pk.
The Great Western Divide
Kern River
Mt. Whitney Govern
WING ROUTE TRAVERSED BY EXPLORING PARTIES
JULIUS BIEN & CO. LITH. N.Y.

STORAGE OF WATER ON KINGS RIVER, CALIFORNIA.

By JOSEPH BARLOW LIPPINCOTT.

LOCATION AND PHYSICAL FEATURES.

Kings River rises on the western slope of the Sierra Nevada, in Fresno County, Cal., draining the crest from Mount Whitney on the south to Mount Goddard on the north. Mount Whitney, with an elevation of 14,898 feet, is the highest mountain in the United States. The divide to the north culminates in numerous peaks, which reach elevations greater than 14,000 feet. This crest probably displays the most rugged and the grandest scenery in our country. Above the 10,000-foot contour the drainage basin of the river is largely bare granite, supporting a scanty vegetation and carved by the action of glaciers. This is clearly shown in Pl II, *A*, and in Pl. III. Between the 10,000- and the 1,000-foot contours the mountains are covered with underbrush and large timber, the most extensive forest of *Sequoia washingtoniana* growing here. (See Pl. IV, *A*, a view southeast of Millwood, at an elevation of 6,000 feet.) The distance from the crest of the mountains to the mouth of the canyon of the river, on a direct line, is approximately 50 miles. Fully 80 per cent of the drainage basin is now included within the boundaries of the Sierra Forest Reserve, which is patrolled for the prevention of fires and illegal herding. The Government will grant no more private holdings within the reserve except for mining or the development of the water resources. This is of prime importance to the irrigated lands below, for it means the conservation of the stream, and the action has been taken none too soon, for great destruction of the forests has already been occasioned by fires and lumbermen. The largest grove of big trees in the State is now being sawed up at Millwood. Pl. IV, *B*, is a view in the Converse Basin, and shows the wasteful, destructive lumbering that has been carried on there.

The river debouches from its mountain drainage basin upon the plains of Fresno, Kings, and Tulare counties. These lands are sometimes referred to as the Kings River delta. They are near the geographic center of the State. Fresno and Hanford are the principal towns. They are about 200 miles distant from San Francisco and Los

Angeles. The counties referred to present a variety of climatic conditions and soils. The altitudes vary from 250 to 14,000 feet. The Coast Range on the west consists of rolling hills, and the country between those mountains and the Sierra Nevada, to the east, is a valley comprising river bottoms and uplands. The Sierra Nevada is divided into three regions—the foothill region, the timber or forest region, and the region of snow and ice. It will readily be understood that with so varied a topography a variety of climatic conditions would necessarily exist. The yearly seasons in San Joaquin Valley are two—a dry season and a wet season. The former usually begins about May 1 and lasts until about the middle of October or the first of November, when the rainy season begins. The average rainfall is 8.79 inches annually at Fresno. There are about 275 days of sunshine in the year. The rains in the winter seldom last more than two or three days at a time. With the exception of very rainy days there is no time during the year that men and teams can not work out of doors. The mean average winter temperature is about 60°; the average summer temperature is 80°. The atmosphere during the summer months is dry, and the heat is not nearly so oppressive as in localities where the atmosphere is damp. The health reports show that Fresno has the lowest death rate of any city in the State. The mountain regions of the eastern portion of the district are always cool. They can be reached in about eight or ten hours' drive from Fresno.

There are probably few equal areas of country where a greater variety of valuable commodities are produced than here. Lumber, gold, copper, petroleum, grain, oranges, lemons, many varieties of deciduous fruits, grapes, raisins, wines, and brandies are produced in commercial quantities. There are more than 500,000 deciduous fruit trees in Fresno County, and the number is being increased each season. There are about 40,000 acres of vineyards producing raisin and wine grapes.[a]

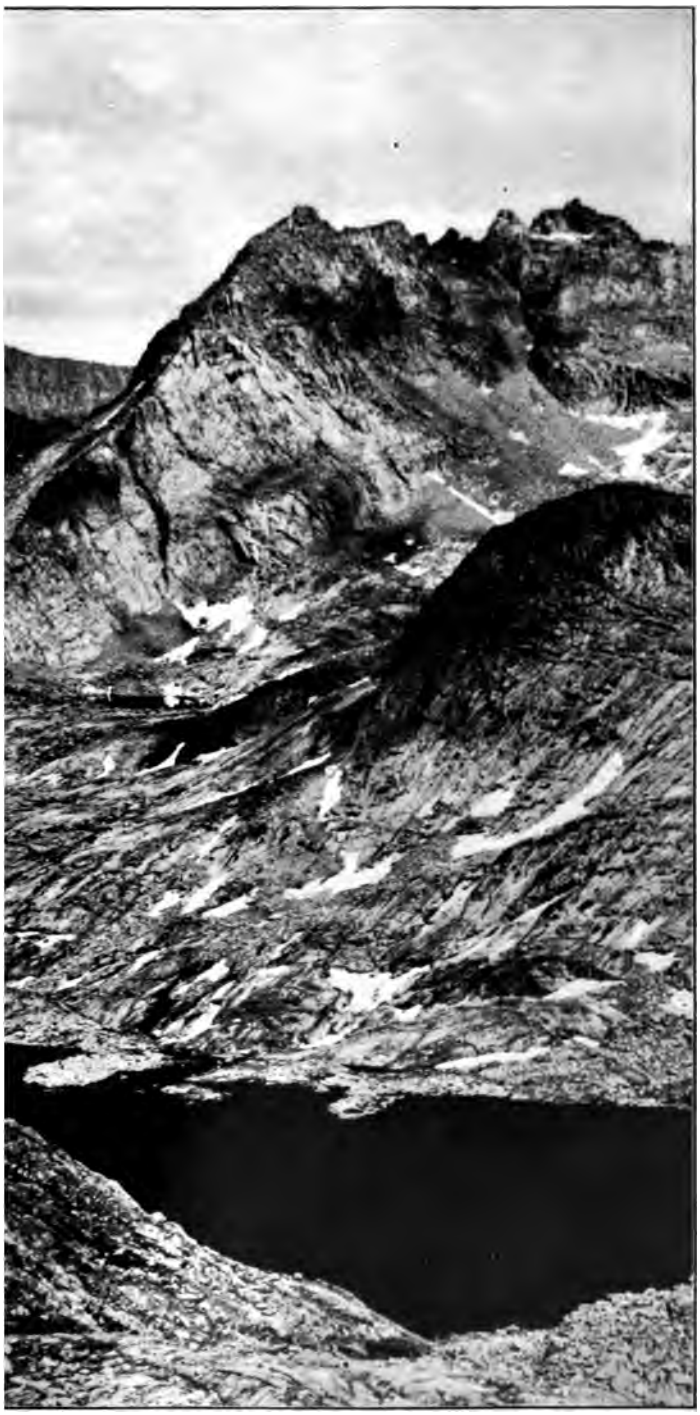
Irrigation is necessary for the production of all varieties of agricultural products, with the possible exception of grains. There are about 625 miles of main irrigation canals, covering 380,000 acres of land on the Kings River delta. It is believed that a good water right on valley lands will add $50 per acre to their value and $90 per acre to the value of the so-called frostless foothill lands. The duty of water may be taken at 2 acre-feet, or 24 inches in depth, each year. Thus an acre-foot of water is worth from $25 to $45 delivered to the land.

As Kings River leaves its canyon, about 12 miles east of Sanger, in Fresno County, it is immediately diverted by a series of canals, shown on the map of the valley lands (Pl. V). The areas irrigated from the river, extending from Fresno on the north to Hanford on the south,

[a] In the fall of 1901 1,400 carloads of oranges were shipped from the district between Fresno and Porterville, and this industry is only in its infancy.

A GENERAL VIEW OF UPPER DRAINAGE BASIN OF KINGS RIVER.

B. HEADWORKS OF *FRESNO* CANAL AND IRRIGATION COMPANY'S SYSTEM.



EST OF SIERRA NEVADA ABOVE TIMBER LINE, KINGS RIVER BASIN.

the most extensive that are watered from any one stream in the State. The canal companies which associated themselves in the Kings River Storage Association decided to contribute for the investigation amounts proportional to the areas of land served. For this purpose each company filed with the association statements of the areas irrigated. These figures, which are given below, possibly represent the areas that are irrigated in good years during the period of spring flood of the river, and in some cases may be in excess of the land actually watered. These canals all have headworks of a rather temporary nature, consisting of rock-filled cribs or brush and rock dams, as shown in Pl. II, *B*.

Lands served by canal companies diverting water from Kings River.

	Acres.
Fresno canal, whole system	160,000
Laguna canal	25,000
Alta Irrigation Company's canal	50,000
Peoples' canal	25,000
Last Chance canal	25,000
Centerville and Kingsburg canal	20,000
Murphy Slough Association	20,000
Lower Kings River	15,000
Fowler Switch canal	12,000
Stinson canal	12,000
Crescent canal	12,000
Emigrants' canal	3,000
Liberty canal	750
Total	379,750

During the May and June flood period there is usually water for the full capacity of all of the diverting canals, estimated at 4,000 second-feet, but the available supply diminishes rapidly after the middle of June, as prior rights take precedence in the diversion. The area watered is on the eastern side of the middle portion of San Joaquin Valley. The lands have a gentle westerly slope from the foothills to the thalweg of the valley. The area irrigable from the river is far in excess of the available water supply. The distance from the foothills to the central drainage lines of the valley is about 10 miles.

This is the great raisin district of California. As already stated, many varieties of deciduous fruits are also successfully grown, and along the foothills it has been demonstrated that semitropical fruits can be matured with success where water is available for continuous irrigation. Porterville, about 50 miles to the south, is one of the most successful orange and lemon districts in the State, and it has been shown, by many scattered orchards, that these fruits can profitably be grown to the east of Sanger. Along the foothills of San Joaquin Valley marked increase in winter temperature occurs within

a rise of a few hundred feet. The citrus belt, as is the case in s
ern California, is a narrow strip of land at the base of the mount

The first irrigators on Kings River naturally diverted the wat
the lower flat lands, where canals could be more cheaply con
In that way the water rights of the river have been applied to
lands, which are relatively low in elevation and upon whic
citrus fruits, the most valuable crop, can not be raised. An inc
in the water supply will therefore permit the application of a p
of this water to the valuable foothill lands. The deciduous f
which are gathered largely during the month of July, do not re
extensive late summer irrigation. The reverse is true of citrus f
which do not ripen until November or December and which re
irrigation throughout the summer. In a similar way alfalfa, the
forage crop of the State, must be irrigated throughout the su
season. In this portion of California lands which are sown to
are capable of producing two crops in case a water supply is ava
for late summer irrigation. An increase in the water supply will
fore permit improved irrigation for areas now served, as well
extension of the irrigated area.

The combined capacity of the canals leading out of Kings Ri
stated to be approximately 4,000 cubic feet per second. In Se
ber, 1898, the low-water summer supply of the river fell as low
cubic feet per second. Possibly the canals during spring floo
divert more than 4,000 second-feet of water, but not more than
second-feet if applied beneficially. It is therefore evident th
late summer supply is wholly inadequate for the demands of the
companies. (This is clearly shown in the discharge diagram
VII and VIII.) The division of this late water has resulted in
litigation, and it is estimated that the canal companies have exp
annually about $40,000 in legal controversies over it. This repr
4 per cent interest on $1,000,000, and results in much bad feelin
in no increase in the supply. During the spring and early su
there is an excessive water supply for all companies, and much
is unused. Little if any water is diverted during the midwinte
son. If summer water could be supplied with certainty it is be
that midwinter irrigation would be practically abandoned. The
power development considered in this report is on the Middle F
Kings River, above all diversions for irrigation and above th
templated diversion of storage water to Clarks Valley, so that n
one would interfere with the proposed power plant.

During the last season (1900) the profits from the irrigated di
around Fresno have exceeded, it is estimated, $2,000,000. This
trates what could be accomplished by extending the irrigation sy
throughout the central valley of California. Land favorably sit
and with a good water right sells for about $60 an acre when
proved, and when in vineyard or orchard it will earn very good re

A FOREST COVER IN SIERRA NEVADA AT ALTITUDE OF 6,000 FEET.

B DESTRUCTIVE LUMBERING IN SIERRA NEVADA.

hat value. The same class of land without an irrigation supply s for about $10 an acre. The water supply therefore represents a ue of $50 an acre. The water has usually been sold with the land. der the Fresno canal a continuous flow of 1 second-foot originally d for $1,600 and was made to apply to 160 acres of land, or at the e of $10 an acre. An additional charge of 62 cents per acre per ar is also made for conveyance of water and repairs. Water rights 160,000 acres of land have been sold by this canal. In the Alta igation district the first cost of water was $5 an acre, with an nual charge of 40 cents per acre for cost of operating. There are ,000 acres under this system. The rights of the Alta district to the er water are subsequent to those of the Fresno canal. A detailed cription of these canals and their rights is contained in Water- pply and Irrigation Paper No. 18, entitled Irrigation near Fresno, C. E. Grunsky. The lands of the Kings River delta are described Mr. Grunsky as follows:

ar Centerville the soil of the upland is a red sandy loam, resting on a yellow hardpan, which is usually at 4 to 6 feet below the surface. Hardpan is not inuous; it disappears frequently at about one-half mile from the margin of pland, where the surface soil becomes lighter and more sandy. At depths of et or more beds of cobble and gravel are found, which in proximity to the iver bottoms afford thorough underdrainage to these lands. The soil is very uctive. Ground water is at 12 to 15 feet below the surface.

stward from Centerville toward Fresno the soil of the plains is a loamy sand. generally rests on a firm clay hardpan, which is sometimes impregnated with Soil is from 1 to 3 feet deep. At the sinks of the several creeks near o the soil is a deep, heavy, red loam, baking on the surface after being Where a hardpan substratum is encountered at all it is at 10 to 30 elow the surface. Westward from the immediate vicinity of the sinks of the eks the soil is a loamy sand, several feet deep, resting on a firm clay hard- The soil far toward the southwest merges into the sandy oils of the alkali hich skirts the edge of Fresno Swamp, and these in turn are succeeded by h peaty alluvium of the swamp lands. To the south of Fresno the sandy Fresno and central California colonies changes to the light so-called ash of ngton colony. The hardpan dips farther below the surface toward the and there are points in the latter colony where it has disappeared alto- . In the southern and southeastern portion of the region commanded by nal system sand predominates. The surface of the country is comparatively a, though occasionally crossed by low sand ridges. Firm hardpan partak- the nature of cemented sand, immediately below the surface soil is rarely It occurs most frequently where the surface presents the peculiar allow appearance.

PRECIPITATION.

e precipitation on the plains between Fresno and Hanford varies 6 inches in the central portion of the valley to 9 inches at Fresno 6 inches at Centerville. The only crop raised without irrigation ain, and this fails except when the rains are opportune. The pitation in the drainage basin ranges from 9 inches in San Joa- Valley, at Fresno, to fully 50 inches on the crest, where it is ly in the form of snow, which lies in great depths on the high

divide until melted by the summer's heat. The accompanyir
give the annual precipitation at Fresno from 1877 to 1900, bo
sive, and at Sacramento from 1849 to 1900, both inclusive.

Annual precipitation, in inches.

FRESNO, CAL.

[Latitude, 36° 43'; longitude, 119° 49'; elevation, 293 feet; observer, Pacific Railway

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.
1877-78	0.00	0.00	0.88	0.42	3.20	1.76	1.91	0.78	T.	0.00	0.00
1878-79	0.00	.20	.56	.22	1.58	.56	.66	1.33	0.06	0.00	0.00
1879-80	0.00	.55	.48	1.07	.46	2.14	.61	1.97	.15	0.00	0.00
1880-81	0.00	0.00	.44	3.05	2.21	.87	.55	1.10	.10	0.00	T.
1881-82	.40	.30	.27	.16	.42	1.04	1.26	1.25	.10	0.00	0.00
1882-83	.34	.05	.73	.70	0.00	.57	2.46	.95	1.36	0.00	0.00
1883-84	0.00	2.00	T.	.34	2.29	3.18	2.81	2.25	1.11	1.39	0.00
1884-85	0.00	.35	.06	3.98	.45	0.00	.53	1.11	.15	0.00	0.00
1885-86	0.00	.06	7.92	1.90	2.58	.58	1.21	2.57	0.00	0.00	0.00
1886-87	0.00	.47	.70	.34	.31	2.80	.09	2.05	.03	.02	0.00
1887-88	.49	.15	.32	1.16	1.75	.13	1.95	.12	.56	T.	T.
1888-89	.06	0.00	2.38	1.71	.34	.32	2.07	.54	.57	0.00	0.00
1889-90	0.00	3.17	1.39	3.87	2.12	.80	1.04	.17	.45	0.00	0.00
1890-91	1.26	0.00	.42	2.30	.79	2.03	.81	.55	.03	.02	0.00
1891-92	.39	0.00	.21	3.08	.37	.68	1.31	.42	1.39	0.00	0.00
1892-93	0.00	.31	.52	2.02	.74	1.75	3.09	.37	0.00	0.00	0.00
1893-94	0.00	T.	.13	.99	1.73	2.95	.25	.10	1.39	1.08	0.00
1894-95	.....	.75	.18	3.67	1.80	1.32	1.95	.78	.62	0.00	0.00
1895-96	.05	0.00	.34	.32	2.89	.06	1.21	2.22	.02	0.00	.07
1896-97	.06	1.28	1.46	1.00	1.93	2.65	1.64	.30	0.00	T.	0.00
1897-98	T.	1.19	.32	.48	.42	1.14	.71	0.00	.79	0.00	0.00
1898-99	1.12	.03	.34	.43	1.92	.02	2.30	.36	.06	.66	0.00
1899-1900	0.00	2.01	1.51	1.00	1.52	.08	.88	1.21	1.97	T.	T.

SACRAMENTO, CAL.

[Elevation, 71 feet; observers, Dr. Thomas M. Logan, Central Pacific Railroad Co
United States Signal Service.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June.	July.
1849-50	0.25	1.50	2.25	12.50	4.50	0.50	10.00	4.25	0.25	0.00	0.00
1850-51	0.00	0.00	T.	T.	.05	.35	1.88	1.14	.00	0.00	0.00
1851-52	1.00	.18	2.14	7.07	.58	.12	6.40	.10	.30	0.00	0.00
1852-53	T.	0.00	6.00	13.41	3.00	2.00	7.00	3.50	1.45	T.	T.
1853-54	T.	T.	1.50	1.54	3.25	8.50	3.25	1.50	.21	.31	0.00
1854-55	T.	1.01	.05	1.15	2.67	3.46	4.20	4.32	1.15	.01	0.00
1855-56	T.	0.00	.75	2.00	4.02	.00	1.40	2.13	1.84	.08	0.00
1856-57	T.	.20	.05	2.40	1.38	4.86	.08	T.	T.	.35	.01
1857-58	0.00	.05	2.41	2.63	2.44	2.46	2.76	1.21	.20	.10	0.00
1858-59	T.	3.01	.15	4.34	.96	3.91	1.64	.98	1.04	0.00	.03
1859-60	.03	0.00	6.49	1.83	2.31	.03	5.11	2.57	2.49	.02	.35
1860-61	.06	.91	.18	4.28	2.67	2.92	3.32	.48	.50	.14	0.00
1861-62	0.00	T.	2.17	8.64	15.04	4.26	2.80	.02	1.81	.01	0.00
1862-63	0.00	.36	.01	2.33	1.73	2.75	2.36	1.69	.36	0.00	T.
1863-64	T.	0.00	1.49	1.82	1.08	.19	1.30	1.08	.74	.49	0.00
1864-65	T.	.12	6.72	7.87	4.78	.71	.48	1.37	.46	0.00	T.
1865-66	.01	.48	2.43	.36	7.70	2.01	2.62	.48	2.55	.10	.03
1866-67	T.	T.	2.43	9.51	3.44	7.10	1.01	1.80	.01	0.00	0.00
1867-68	.01	0.00	3.81	12.85	6.04	3.15	4.35	2.31	.27	T.	0.00
1868-69	0.00	0.00	.77	2.61	4.79	3.63	2.94	1.24	.65	.01	0.00
1869-70	T.	2.12	.85	1.96	1.37	3.24	1.64	2.12	.25	T.	T.
1870-71	0.00	.02	.58	.97	2.48	1.92	.69	1.45	.76	T.	0.00
1871-72	T.	.21	1.22	10.59	6.04	4.74	1.94	.61	.28	.02	0.00
1872-73	T.	.22	1.93	5.39	1.53	4.36	.55	.51	0.00	T.	.02
1873-74	0.00	.31	1.87	10.12	5.30	1.86	3.05	.89	.37	0.00	0.00
1874-75	.05	2.29	3.80	.44	8.81	.03	1.26	0.00	.04	1.08	0.00
1875-76	0.00	.04	6.29	5.52	4.99	3.75	4.15	1.10	.15	0.00	.21
1876-77	0.00	3.45	.30	0.00	2.77	1.04	.56	.19	.64	0.00	0.00
1877-78	0.00	.73	1.07	1.43	9.26	8.04	3.09	1.07	.17	0.00	0.00
1878-79	.29	.55	.51	.47	3.18	3.88	4.88	2.66	1.30	.13	T.
1879-80	0.00	.88	2.05	3.41	1.64	1.83	1.70	14.20	.76	0.00	T.
1880-81	0.00	0.00	.05	11.81	6.14	5.06	1.37	1.64	T.	.50	T.
1881-82	.30	.55	1.88	3.27	1.89	2.40	3.78	1.39	.35	.10	T.
1882-83	.57	2.63	3.22	1.13	2.23	1.11	3.70	.67	2.85	0.00	0.00
1883-84	.80	.97	.61	.44	3.43	4.46	8.14	4.32	1.16	1.45	0.00
1884-85	.60	2.01	0.00	10.45	2.16	.49	.76	.68	T.	.11	T.
1885-86	.08	.02	11.34	5.76	7.95	.29	2.68	4.08	.07	0.00	0.00
1886-87	0.00	.68	.21	2.21	1.12	6.28	.94	2.53	T.	0.00	0.00
1887-88	.02	0.00	.45	2.09	4.81	.55	3.04	.10	.40	.08	T.

A. RED MOUNTAIN GAGING STATION ON KINGS RIVER.

B. FALLS IN CREEK ABOVE EAST LAKE.

Annual precipitation in inches—Continued.

SACRAMENTO, CAL.—Continued.

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
89	0.55	0.00	4.28	4.63	0.15	0.33	6.25	0.26	3.25	0.25	0.00	0.00	19.95
90	0.00	6.02	3.15	7.82	6.62	4.06	3.00	1.33	1.80	0.00	0.00	T.	33.80
91	.80	T.	0.00	3.34	.53	6.61	1.78	2.04	.66	.05	T.	0.00	15.81
92	.10	.10	.48	3.28	1.78	2.84	3.02	1.20	2.38	T.	0.00	0.00	15.18
93	.18	.70	6.60	4.90	3.27	2.66	3.51	1.08	1.05	0.00	T.	0.00	23.95
94	.22	.12	2.92	1.76	4.17	3.92	.74	.34	1.70	.46	T.	T.	16.35
95	.88	1.06	.48	8.86	8.42	1.84	1.20	.86	.51	0.00	.04	T.	24.15
96	1.26	.17	1.54	1.54	9.76	.09	2.57	5.34	.92	0.00	T.	.20	23.39
97	.31	.55	3.56	1.76	3.66	4.15	2.54	.25	.30	.04	0.00	0.00	17.12
98	.16	1.96	.61	1.64	.98	3.19	.04	.28	1.50	.14	0.00	0.00	10.50
99	.36	.64	.61	2.30	3.94	.04	6.02	.10	.54	.49	0.00	.02	15.06
1900	0.00	4.46	2.62	2.91	3.54	.32	1.61	1.88	2.88	T.	T.	0.00	20.22

T indicates trace.

No rainfall records of extended duration have been maintained the higher portion of the drainage basin. A few miles to the north, the same slope, at Summerdale, the record from 1896 to 1899 shows average of 47.86 inches. At Sequoia, on the same range and slope, miles to the north, the average for three years, from 1897 to 1900, as 46.90 inches, the elevation being 4,452 feet. At Second Garrotte, out 60 miles to the northwest, on the same slope of the Sierra, a irteen-year record shows an average rainfall of 38.98 inches, the evation being 2,900 feet.

The rainy season in California extends from about the first of Octo- r until about the first of April. The maximum monthly precipita- on probably occurs during the month of January. In the foothills id valleys there is practically no rainfall during the summer. In the ountains above 10,000 feet in elevation, however, frequent thunder- orms occur in the afternoons, particularly during the months of July id August. The rainfall on the western slope of the sierras, in the sin of the Tuolumne, increases at the rate of about 0.8 inch per 0 feet until an elevation of approximately 7,000 feet is reached, yond which there probably is no increase, though data bearing on e subject are meager. The mean annual rainfall for the basin is obably about 40 inches and the stream run-off about 40 per cent of e rainfall.

REGIMEN OF RIVER.

The period of minimum flow of the streams is in September and ctober. The rains falling in the foothills in the late autumn increase mewhat the fall discharge of the river, but the heavier precipitation the higher mountains is retained until melted during the following mmer. The river gradually increases in volume after the first of bruary, in normal years usually reaching a maximum between May and June 10. This spring water comes from the melting of the eat snow banks above the 4,000-foot contour. Probably the greatest ods that occur in this drainage basin are brought about by warm ring rains falling upon the snow in the foothills. During mid

summer the flow of the river is maintained mostly from the melting of the snow banks and small glaciers near the crest. These never entirely disappear. It is probable that during the mid and late summer period there is a greater volume of water in the drainage lines at the 3,000- or 4,000-foot contour than there is in the main stream at the mouth of the canyon, as the lower elevations of the drainage basin do not then contribute materially to the flow, and considerable loss by evaporation occurs in the lower reaches of the river.

In November, 1878, the California State engineering department began measurements of the discharge of Kings River at the base of the foothills and continued them until October, 1883. The point of measurement was above all diversions by the canals and shows the total discharge of the stream.[a] The results of these measurements are given in the following tables:

Estimated monthly discharge of Kings River at Slate Point, Cal.

[Drainage area, 1,742 square miles.]

Month.	Mean discharge in second-feet.	Total for month in acre-feet.	Run-off.	
			Depth in inches.	Second-feet per square mile.
1878-79.				
November	300	17,851	0.19	0.17
December	290	17,831	.18	.16
January	370	22,750	.24	.21
February	870	48,317	.52	.50
March	1,970	121,130	1.30	1.13
April	4,750	282,645	3.03	2.72
May	5,090	312,972	3.37	2.92
June	3,760	223,736	2.40	2.15
July	1,650	101,455	1.08	.94
August	380	23,366	.25	.22
September	770	16,066	.16	.14
October	280	17,217	.18	.16
The year	1,665	1,205,336	12.90	.95
1879-80.				
November	400	23,802	.26	.23
December	1,440	88,542	.94	.82
January	720	44,271	.47	.41
February	1,040	60,396	.65	.60
March	1,120	68,866	.74	.64
April	5,230	311,207	3.30	3.00
May	7,120	437,792	4.63	4.01
June	9,540	567,669	6.06	5.41
July	4,800	295,141	2.44	2.11
August	1,150	70,711	.76	.66
September	370	22,017	.23	.21
October	220	13,527	.15	.13
The year	2,763	2,003,941	20.63	1.32
1880-81.				
November	220	13,091	.13	.12
December	510	31,359	.33	.29
January	870	53,494	.58	.50
February	2,430	134,955	1.45	1.39
March	1,900	106,876	1.26	1.09
April	5,800	345,174	3.71	3.33
May	8,220	505,428	5.44	4.71
June	5,010	298,116	3.21	2.88
July	4,790	294,526	3.17	2.75
August	650	39,967	.43	.37
September	340	20,231	.21	.19
October	250	15,372	.16	.14
The year	2,583	1,858,489	20.08	1.48

[a] Physical Data and Statistics of California, p. 452.

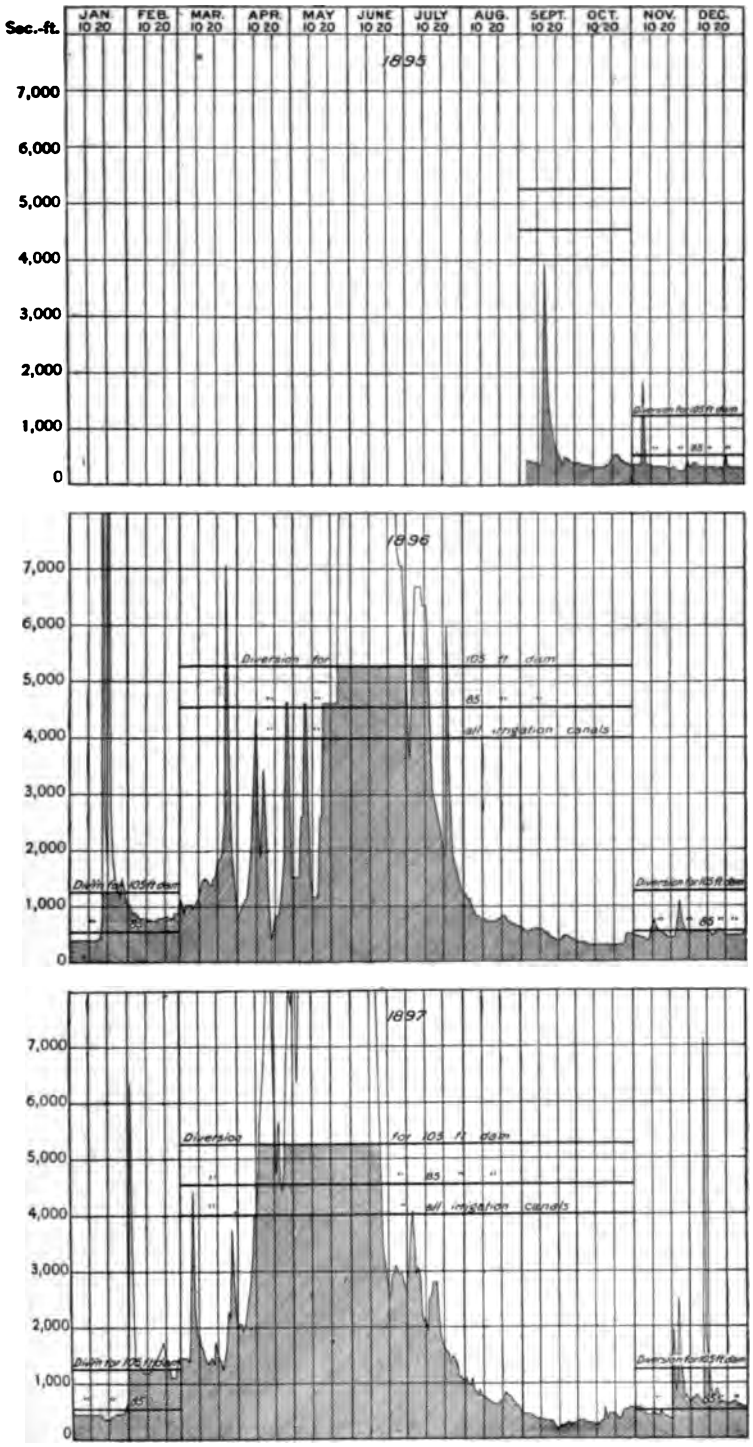


DIAGRAM SHOWING DISCHARGE OF KINGS RIVER AT RED MOUNTAIN GAGING STATION FOR YEARS 1895 TO 1897.

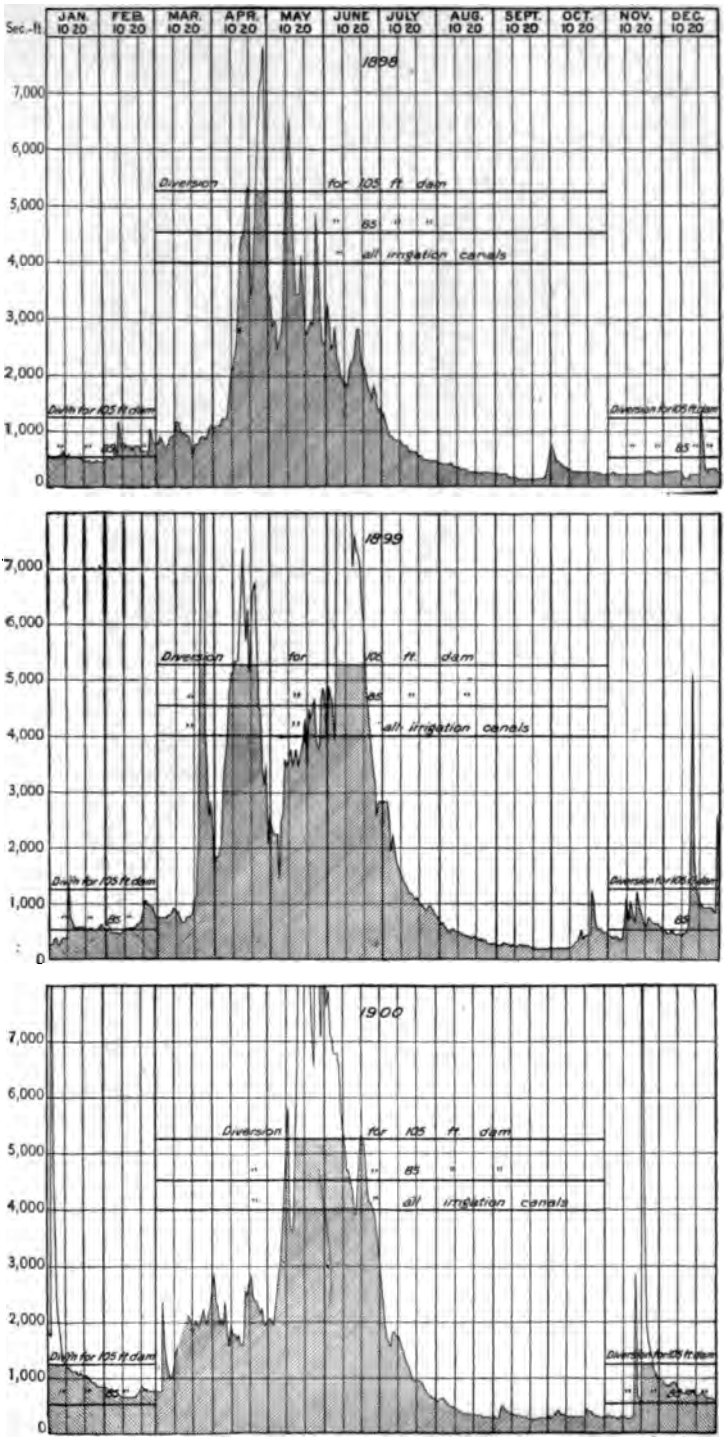


DIAGRAM SHOWING DISCHARGE OF KINGS RIVER AT RED MOUNTAIN GAGING STATION FOR YEARS 1898 TO 1900.

nonthly discharge of Kings River at Slate Point, Cal.—Continued.

Month.	Mean discharge in second-feet.	Total for month in acre-feet.	Run-off.	
			Depth in inches.	Second-feet per square mile.
1881-82.				
	220	13,686	0.14	0.13
	280	15,987	.17	.15
	380	23,366	.25	.22
	440	24,436	.26	.25
	1,250	76,859	.83	.72
	3,170	188,628	2.03	1.82
	9,190	565,071	6.12	5.28
	6,410	381,421	4.10	3.68
	2,020	124,205	1.34	1.16
	620	36,122	.41	.36
	390	23,207	.24	.22
	610	37,507	.40	.35
	2,081	1,512,496	16.29	1.20
1882-83.				
	470	27,967	.30	.27
	340	20,906	.22	.19
	320	19,676	.21	.18
	340	18,883	.22	.19
	1,050	64,562	.09	.60
	2,220	132,090	1.42	1.27
	6,700	411,967	4.48	3.85
	6,730	400,463	4.10	3.68
	1,460	89,772	.97	.84
	600	36,893	.39	.34
	480	28,562	.30	.27
	420	25,825	.28	.24
	1,761	1,277,575	13.58	.99

ɔtember, 1895, the United States Geological Survey has ıirements of the total flow of Kings River above the diver- anals. The point of observation is known as Red Moun- Pl. VI, *A*.) It is 3 or 4 miles above the mouth of the can- thin a mile of the proposed point of diversion of Kings ɔ Clarks Valley reservoir, described further on. The data ı daily fluctuation of the river as measured by the Califor- ngineering department are not available, but the aggre- ly and seasonal discharge for the years given by the State ow greater volume than the aggregate discharge as meas- e Geological Survey for the minimum year—1898. The by the Geological Survey is given in the following tables n graphically in the diagrams forming Pls. VII and VIII:

ɔted monthly discharge of Kings River at Red Mountain, Cal.

[Drainage area, 1,742 square miles.]

ɔnth.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
895.						
	3,920	360	778.0	46,294	0.50	0.45
	520	320	371.0	22,812	.24	.21
	1,834	250	368.0	21,898	.23	.21
	520	250	328.0	20,168	.22	.19
ths	3,920	250	461.0	111,172	1.19	.27

Estimated monthly discharge of Kings River at Red Mountain, Cal.—Continu

Month.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Sec feet squ m
1896.						
January	11,020	390	1,474.8	90,682	0.98	
February	1,140	728	825.4	47,477	.51	
March	7,020	820	1,710.6	105,181	1.13	
April	4,600	390	1,938.5	115,349	1.24	
May	22,100	1,140	5,918.1	363,890	3.90	
June	18,920	5,160	12,737.3	757,922	8.15	
July	6,680	1,212	3,742.2	230,110	2.48	
August	1,212	590	759.9	48,938	.52	
September	590	390	491.3	29,234	.31	
October	510	310	350.0	21,520	.23	
November	1,076	390	538.5	32,043	.35	
December	550	470	498.4	30,645	.33	
The year	22,100	310	2,585.1	1,872,991	20.13	
1897.						
January	624	360	437.0	26,870	.29	
February	6,344	1,100	1,631.0	90,581	.96	
March	4,408	1,240	1,884.0	115,843	1.22	
April	9,380	1,930	5,318.0	316,442	3.33	
May	22,732	6,344	14,470.0	889,731	9.40	
June	10,580	2,520	6,145.0	365,652	3.87	
July	4,040	1,036	2,177.0	133,859	1.41	
August	1,100	440	739.0	45,440	.47	
September	480	250	320.0	19,577	.20	
October	572	270	394.0	24,226	.25	
November	2,520	360	692.0	41,177	.44	
December	8,348	572	985.0	60,566	.63	
The year	22,732	250	2,933.0	2,129,964	22.47	
1898.						
January	624	440	506.0	31,113	.33	
February	1,170	480	705.0	39,154	.41	
March	1,170	520	895.0	55,032	.58	
April	7,820	1,036	3,547.0	211,061	2.23	
May	6,520	2,450	3,530.0	217,422	2.29	
June	3,280	1,310	2,122.0	126,267	1.34	
July	1,310	440	696.0	42,796	.45	
August	400	215	320.0	19,676	.21	
September	780	145	204.0	12,139	.13	
October	728	215	320.0	19,676	.21	
November	285	215	231.0	13,745	.14	
December	1,450	180	315.0	19,369	.21	
The year	7,820	145	1,116.0	807,450	8.53	
1899.						
January	1,310	250	513.0	31,543	.33	
February	1,036	440	660.0	36,655	.39	
March	20,200	624	2,165.0	133,121	1.41	
April	7,300	1,834	4,512.0	268,483	2.83	
May	4,780	1,450	3,568.0	219,388	2.32	
June	10,300	2,852	6,077.0	361,607	3.81	
July	2,852	676	1,411.0	86,759	.91	
August	624	250	411.0	25,271	.26	
September	285	180	215.0	12,793	.13	
October	1,205	180	378.0	23,242	.24	
November	1,240	345	638.0	37,964	.40	
December	5,096	400	991.0	60,934	.64	
The year	20,200	180	1,795.0	1,297,760	13.67	
1900.						
January	12,700	849	1,689.0	103,853	1.12	
February	849	676	748.0	41,542	.45	
March	2,584	728	1,712.0	105,267	1.13	
April	2,852	1,546	2,098.0	124,840	1.34	
May	9,400	1,930	5,881.0	361,666	3.90	
June	7,900	2,986	5,127.0	305,078	3.27	
July	2,584	572	1,278.0	78,581	.84	
August	624	250	398.0	24,472	.26	
September	520	215	301.0	17,911	.19	
October	440	215	309.0	19,000	.21	
November	15,700	250	1,310.0	77,950	.83	
December	972	572	726.0	44,640	.48	
The year	15,700	215	1,798.0	1,304,743	14.02	

st five years, during which records have been kept by the
l Survey, have been years of relative drought in California,
e seen by the Fresno rainfall records (page 16), which are
ıs since 1877. The twenty-three-year mean at Fresno is 8.79
ıd that of the last five years is 8.26 inches. The precipita-
ıg the winter of 1897–98 was within 0.08 inch of the smallest
rded. It is believed that the records of the Geological Sur-
sent a minimum annual flow of the river, and that estimates
on them will be conservative.

s once in ten years seasons of extremely low discharge may
ıen there may be a shortage of water for the systems con-
l in this report, but it is believed that the shortage will not
enough to be seriously detrimental to the interests depending
water supply for either storage or power. It would hardly
e necessary, or good engineering, to plan works for a mini-
, which probably will not occur more than once in ten years,
the minimum year 80 or 90 per cent of the water supply
e available. A notable case in point is the Sweetwater reser-
ir was entirely dry during the season of 1899–1900, yet by
l cultivation of the orchards and the use of temporary
plants a good crop was harvested from a very reduced
water. It may be stated that Kings River, which drains
are miles of the western slopes of the Sierra Nevada, from
perpetual snow and from some of the finest forests of the
ı be relied upon for a great water supply. It is one of the
reams in the State from which water is obtained for irriga-
oses.

lowing is a general summary of the total volume of the river.
es for the first five years are from the records of the State
ng department, those for the last five years are from the
the Geological Survey.

Annual discharge of Kings River.

	Acre-feet.
	1,205,336
	2,003,941
	1,858,489
	1,512,495
	1,277,575
year mean	1,571,567
	1,872,991
	2,129,964
	807,450
	1,297,760
	1,304,838
year mean	1,482,601

The available supply from the river is discussed further in connection with the Pine Flat reservoir site (pages 30 to 33) and the Clarks Valley reservoir site (pages 39 to 42).

EVAPORATION AND SEEPAGE.

Evaporation observations were made by the State engineering department of California from November, 1881, to October, 1885, inclusive, at Kingsburg, on Kings River, at an elevation of 297 feet above sea and 20 miles southwest from the proposed Clarks Valley reservoir site. The results of these observations are given in the following table. A pan was floated in the river and observations were made daily thereon, the pan being kept at practically the same temperature as the water in the stream. The total mean annual evaporation observed was 3.851 feet.

Evaporation at Kingsburg, on Kings River.[a]

[Elevation, 297 feet.]

Month.	Depth in feet.			
	1881–82.	1882–83.	1883–84.	1884–85.
November	0.220	0.115	0.170	0.200
December	.050	.085	.080	.180
January	.090	.090	.105	.010
February	.115	.100	.050	.140
March	.180	.305	.090	.240
April	.200	.270	.160	.160
May	.305	.160	.320	.340
June	.475	.500	.295	.660
July	.660	.780	.380	.710
August	.665	.920	.370	.930
September	.475	.730	.320	.640
October	.135	.400	.350	.470
The year	3.630	4.405	2.690	4.680

[a] Physical Data and Statistics of California, p. 378.

The amount of water lost by seepage and evaporation by the Kings River canals was made the subject of careful study by C. E. Grunsky, for the California State engineering department, in the summer of 1882, the results of which are given in Water-Supply and Irrigation Paper of the United States Geological Survey No. 18, page 74. The actual loss by evaporation from the surface of the water while in transit in the canals is very small; probably 1 per cent would cover it. The greater loss is occasioned by seepage. The canals of this district are not all built on true grades, and some of them have swamps and pools along their courses. In one instance—on the Centerville and Kingsburg canal—a loss of 52 second-feet was shown in 1 mile. The observations by Mr. Grunsky were made nearly twenty years ago, when the water plane was not so near the surface as it now is, and consequently the seepage losses were greater than now. The general

esult of his observations shows a loss of 307.11 second-feet in 50.8 niles out of a total diversion of 860.83 second-feet. This amounts to 6.05 second-feet to the mile, or 36 per cent of the total diversion. The measurements on the river and on the Fresno canal were made from about a half mile to 20.3 miles below its head, and showed a loss of 64.3 second-feet out of 133.83 second-feet diverted. On the Fresno canal the loss from about 1¼ to 23½ miles below the headworks was 104.52 second-feet out of 381 second-feet diverted. On the Centerville and Kingsburg canal, from a half mile to 7 miles from the headworks, the loss was 138.29 second-feet out of 346 second-feet diverted. Relatively, the greater rate of loss in the canals was in the first few miles from the headworks, where they are in porous soils, close together, and approximately parallel.

The loss of water from a canal by seepage is governed by the rate of percolation, the area through which percolation occurs, and the period of time during which a given unit of water is exposed. The greater the depth of water in a canal the greater the velocity of flow, and consequently the less time is a given unit of water exposed to loss by percolation in any section of the canal. This increase of velocity due to greater depth is relatively larger than the increase of wetted area through which percolation takes place. For instance, if an earthen canal 40 feet wide has a slope of 5.28 feet to the mile and a depth of water of 2 feet it would discharge 220 second-feet with a velocity of 2.74 feet per second. With other conditions the same, if the depth of water were increased to 4 feet the discharge would be 670 second-feet with a velocity of 4.19 feet per second. Thus, while the wetted area exposed to percolation increases 9 per cent the discharge trebles. For the sake of comparison, suppose the velocity of percolation were 0.10 foot per hour. Then in the canal flowing 2 feet deep the loss per second per lineal foot of canal would be 0.00122 second-foot, and with the canal flowing water 4 feet in depth it would be 0.00133 second-foot. Comparing this loss with the respective volumes carried by the two canals, we find that the relative loss of water in the large canal is but 40 per cent of that in the small canal.

If the three canals referred to had been consolidated and all water run through the Kings River and Fresno canal, then using Mr. Grunsky's data and the foregoing reasoning it would be safe to say that in the first 11¼ miles of the Fresno canal 95.51 second-feet would have been saved, and in the first 6.5 miles of the Centerville and Kingsburg canal 138.29 second-feet would have been saved, or 233.80 second-feet out of a total loss of 307.11 second-feet. This would reduce the loss to 8.5 per cent of the whole, instead of 36 per cent, which Mr. Grunsky found.

It must be remembered, however, that the losses described occurred in 50.8 miles of main canals, during the early stages of irrigation

development, and that probably there would be on an average as much more lost in the distribution laterals. Enough data are not at hand to draw accurate conclusions, but it is believed that under favorable conditions fully 25 per cent of the river water would be lost in reaching the land to be irrigated.

If water be drawn from reservoirs to supplement the low-water supply of the canals it will be water added to most of the canals and not subject to so heavy a rate of loss as, say, 25 per cent of the water first diverted; probably 15 per cent would be nearer the actual amount.[a]

RECONNAISSANCE OF BASIN.

In the investigation of the large basin of Kings River, which from a hydrographic point of view was practically unknown, it was decided to equip two parties for the season's work. Accordingly a reconnaissance party was organized and placed in charge of Mr. E. G. Hamilton, topographer from the United States Geological Survey. The work of this party was largely exploratory, but at the close of the season the Clarks Valley reservoir site was surveyed by Mr. Hamilton. The reconnaissance party was instructed to visit all portions of the drainage basin, make instrumental examinations of all possible reservoir sites, and at the end of each month report the character of the sites found. A second party was organized, under the direction of Mr. H. E. Green, an engineer of extended experience in the construction of storage reservoirs, for the purpose of making more detailed surveys of the better sites found by the exploration party. The reconnaissance party reported upon and sketched seven reservoir sites, four of which were surveyed under the direction of Mr. Green.

The following instructions were given to the engineers for their guidance in making reports:

Report on reservoir survey.

(1) Give name of engineer in charge and date of survey.
(2) Name of locality.
(3) Streams tributary to site.
(4) Land title to site.
(5) If possible tie reservoir surveys to land surveys. The point of reservoir survey to be tied in is preferably the ends of the dam.
(6) If the land is not subdivided, tie reservoir survey to prominent natural objects.
(7) Estimate area of tributary drainage basin.
(8) Give general statement of elevation of drainage basin and elevation of reservoir site.
(9) State whether drainage basin is timbered or bare hills.
(10) Compute water supply.
(11) Give capacity of reservoir with various heights of dam.
(12) State character of material for dam; earth, rock fill, or concrete.

[a] See addenda on page 99.

(13) For purposes of preliminary estimate consider—
Earthen dam 20 feet wide on top; 2½ to 1 slope on inner face, 1½ to 1 on outer face. Describe the quality of the available earth, which should be a clay, sand, and rock, also give length of haul.
Rock-fill dam 20 feet wide on top; 1½ to 1 outer slope, 1 to 1 inner slope. State position of available rock supply, give probable cost of cement delivered on the ground, and available timber for inner face and cost thereof.
Concrete dam. State the proximity and relative elevation of quarries, and the cost per barrel of cement delivered on the ground.
(14) Report on probable foundations for dam.
(15) Estimate on the cost of dam.
(16) State cost per acre-foot of water stored.*

The requisites of a reservoir site are numerous and exacting, as follows:

(1) There must be an available water supply sufficient to fill the basin.
(2) There must be a basin to hold this supply.
(3) There must be a good dam site.
(4) There must be good materials of which to make a dam.
(5) The foundations must be able to sustain the dam.
(6) There must be available lands upon which to put the water.
(7) The entire project must be on a commercial basis.

There are a large number of sites on the river which were popularly supposed to be good but which proved to be objectionable, owing to the lack of some one of the foregoing vital requisites.

The field party, which consisted of a topographer, a rodman, and a cook, left Sanger, in Fresno County, a station on the Southern Pacific Railroad at an elevation of 370 feet, on May 22, 1900. The route of travel is shown on the map, Pl. I, which was furnished by Mr. J. N. Le Conte for use in connection with this report.

The first site investigated was the upper Clarks Valley, 16 miles east of Sanger, 10 miles north of Reedley, and 1 mile north of where the stage road from Sanger to Millwood crosses Wahtoke Creek; elevation, 500 feet. This site is at the upper end of the main Clarks Valley reservoir site, and is included by it. It is shown on the map of the Clarks Valley site (Pl. XIII), and is not estimated upon separately.

From Clarks Valley the party went back to Kings River, and following along its east bank to the mouth of Mill Creek ascended that creek 4 miles, to McHaley's ranch, at an elevation of 650 feet. A half mile above McHaley's ranch a reservoir site was surveyed, and it was found that a concrete dam 195 feet in height would store 3,500 acre-feet of water at a cost of $130 per acre-foot, which of course is prohibitive.

After spending two days in the hills between Mill Creek and Kings River the party went by trail from McHaley's ranch to Squaw Valley, then along the Millwood stage road to Dunlap. At Dunlap a stay of

*An acre-foot of water is an amount sufficient to cover 1 acre to a depth of 1 foot.

three days was made to permit an investigation of the drainage of Mill Creek. After leaving Dunlap the party followed the stage road to Millwood, then took the trail through the General Grant National Park to Huckleberry Meadow, a small meadow 8 miles northeast of Millwood and at an elevation of 6,000 feet. With Huckleberry Meadow as a base of supplies, trips were made to the meadows and basins within a radius of 20 miles. The largest of these meadows are Converse Basin, 10 miles northwesterly from Huckleberry Meadow; Bearskin Meadow, 6 miles to the east; Burton Meadow, 10 miles to the east; Squawskin Meadow, 14 miles to the east; and Big Meadows, 16 miles to the south. Big Meadows is the only one of these reservoir sites that has a good dam site, but as it is on the divide between Kings and Kaweah rivers and has only 8 square miles of watershed it was not mapped. The Long Meadow reservoir site, which is in this locality, was surveyed by Mr. Green, and the results of the survey are given on pages 44 to 46.

SOUTH FORK.

There are two trails leading from Huckleberry Meadow to the grand canyon of Kings River. The upper trail is the shorter and better, but there is no bridge across Boulder Creek and it is dangerous to attempt to ford it during high water. On the lower trail, however, there is a bridge, which made it possible to move the camp from Huckleberry Meadow to the grand canyon of the Kings, where two sites were surveyed, one with the dam site a half mile below the junction of Copper Creek and the South Fork of Kings River, in sec. 14, T. 13 S., R. 31 E., Mount Diablo base and meridian, at an elevation of 5,000 feet; the other, 5 miles farther down the South Fork of Kings River, with the dam site a half mile below the mouth of Lewis Creek, in sec. 10, T. 13 S., R. 30 E., at an elevation of 4,300 feet.

At either of these sites it would be necessary to construct an overflow dam on the South Fork. A 210-foot dam at the site below the mouth of Copper Creek would store approximately 29,378 acre-feet of water. The estimated cost of storage is about $67 per acre-foot for a rubble masonry dam. A 200-foot dam at the lower site would store 14,100 acre-feet, and the estimated cost of storage is $178 per acre-foot. These dams would have to be made of hydraulic-cement masonry. In both of these cases the excessive cost per acre-foot stored renders the construction of the dams impracticable.

A view in the canyon of the South Fork near the mouth of Copper Creek is shown in Pl. IX.

From the site at the mouth of Lewis Creek the bed of the South Fork down to its junction with the Middle Fork is narrow and has a heavy grade.

CLIFFS ON SOUTH FORK OF KINGS RIVER

UBBS CREEK AND HEADWATERS OF SOUTH FORK.

ıannels of both of these streams are narrow, averaging from 000 feet in width, with high granite walls on either side, and ıll of from 50 to 200 feet to the mile. Near their headwaters erous small lakes, one of which, Lake Charlotte, was mapped. 1.) This lake is on the headwaters of Bubbs Creek, near the etween that stream and the South Fork of Kings River, at an n of 10,500 feet, and has a drainage area of about 8 square The surface area of the lake is 24 acres and the depth of the ɔout 30 feet. Owing to its inaccessibility and to the lack of a m site it was not considered as a possible storage basin.
I, *B*, is a view of the falls in a creek above East Lake in the 'ork drainage.

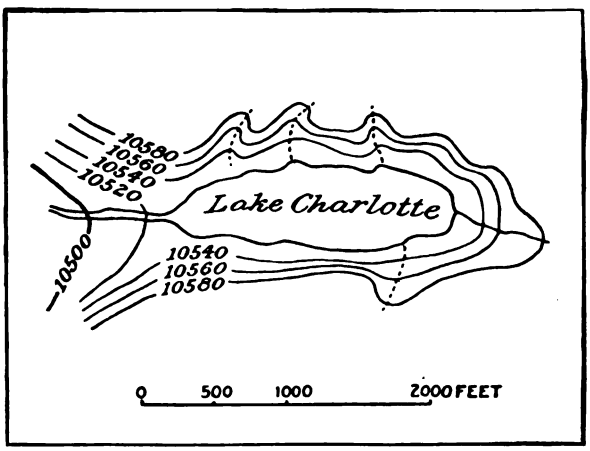


FIG. 1.—Lake Charlotte reservoir site.

PARADISE VALLEY.

ise Valley, on the South Fork of Kings River, 5 miles above ıth of Bubbs Creek and at an elevation of 6,500 feet, was l, but its floor, although in places 2,000 feet wide, has a fall ɔt in 1,000 feet, and it therefore is not a good reservoir site. ɔ inaccessible.

ROARING RIVER AND SUGARLOAF CREEK.

ɔhe headwaters of these streams are numerous small meadows, one that was visited has a good dam site. The channels of ı streams are narrow gorges with falls or slopes varying from ɔ 500 feet to the mile. Leaving the South Fork of Kings River l week in July, the party started for Simpson Meadows, on lle Fork, spending several days in reconnaissance en route, one exception (Granite Basin) no reservoir sites of any value nd. The Granite Basin site was examined by Mr. Green, the f the examination being given on page 48.

SIMPSON MEADOWS.

The Simpson Meadows, on the Middle Fork of Kings River at a elevation of 6,000 feet, have an average width of 3,000 feet. The larger part of the meadows is on the east side of the river, and extends a mile above the mouth of Goddard Creek and 3 miles below it. A dam 200 feet in height would be required to flood the meadows. Its top length would be 3,000 feet, and the cost would be so great as to make it prohibitive. While camped in Simpson Meadows the party spent several days in exploring Cartridge, Palisade, Goddard, and Disappearing creeks and the headwaters of the Middle Fork, but found no storage basins of value.

Leaving Simpson Meadows the second week in August the party followed the Tunema and Collins trail to Cliff Camp, on the North Fork of the river. (See Pl. X.) Between the Middle and North forks are numerous small meadows, most of them near the summits of the ridges, with from 3 to 5 square miles of watershed, but not one of them has a good dam site or an extensive drainage basin.

DUSY MEADOWS.

On the North Fork two reservoir sites were mapped—the Dusy Meadows site and one three-fourths of a mile farther upstream. At the latter site, which is the smaller of the two, a concrete overflow dam 150 feet high would store 5,440 acre-feet of water, but at a prohibitive cost—about $276 per acre-foot stored.

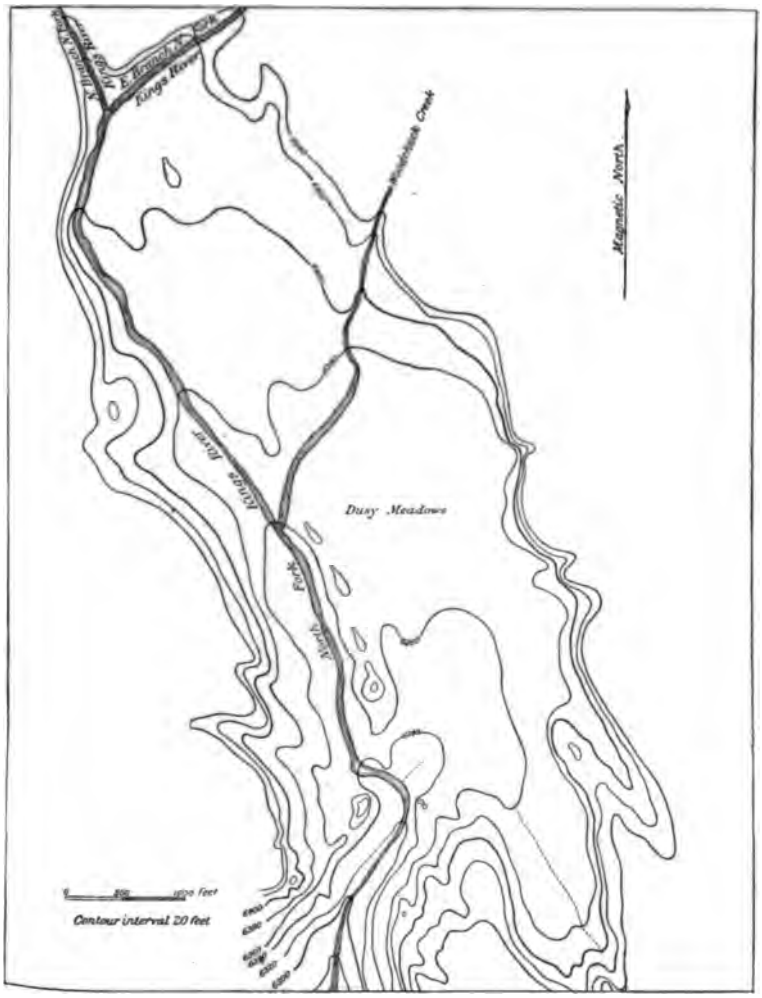
The Dusy Meadows reservoir site is in Fresno County, on the North Fork of Kings River, in sec. 36, T. 10 S., R. 27 E., and sec. 31, T. 10 S., R. 28 E., Mount Diablo base and meridian. The drainage area of the basin of the North Fork above the reservoir site is 144 square miles, at an average elevation of 9,000 feet above sea level. Assuming the average annual rainfall to be 39 inches and 620 acre-feet the annual run-off per square mile, we have 88,280 acre-feet as the amount of water available for storage purposes from the drainage basin. The elevation of the dam site, as determined from aneroid measurements, is 6,300 feet above the sea, and the capacity of the reservoir at different heights of the water would be as follows:

Capacity of Dusy Meadows reservoir site.

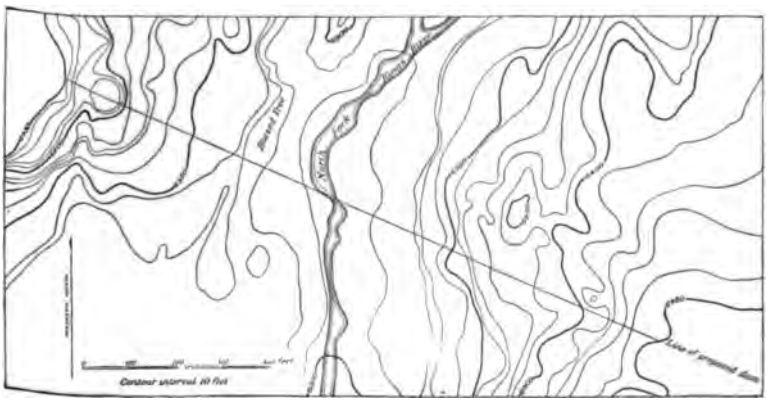
	Acre-feet.
Between 20- and 40-foot levels	180
Between 40- and 60-foot levels	860
Between 60- and 80-foot levels	2,930
Between 80- and 100-foot levels	5,460
Between 100- and 120-foot levels	7,420
Total	16,850

The reservoir site is mapped in Pl. XI, *A*, and the dam site in Pl. XI, *B*. A loose rock dam 125 feet in height, faced with timber, i

LIFF CAMP, ON NORTH FORK OF KINGS RIVER, AT LOW-WATER STAGE OF STREAM.



A. CONTOUR MAP OF DUSY MEADOWS RESERVOIR SITE.



B. CONTOUR MAP OF DUSY MEADOWS DAM SITE.

imated upon for this site. There is plenty of granite rock on both les of the dam site which could readily be transported by cable or ier mechanical devices, and there are at hand large quantities of nding timber, both yellow pine and fir.

In the following estimate of cost the quantities given are for a dam th slopes of ½ to 1 and 1 to 1, with a width of 20 feet on top, a nk face 6 inches thick, and sills 12 inches by 12 inches, with 12 t between centers.

Estimate of cost of Dusy Meadows dam.

k, 378,000 cubic yards at $0.75	$283,500	
nking for face, 656,000 feet, B. M., at $40	26,240	
s, 111,000 feet, B. M., at $40	4,440	
or in laying 767,000 feet, B. M., at $6	4,600	
		$318,780
o spillways, one on each side of the dam, each having a capacity of ,300 second-feet, 45,000 cubic yards of rock at $1		45,000
hed outlet tunnel 4 feet by 6 feet by 400 feet long, cement ined, at $10 per lineal foot	$4,000	
wer and gates	8,000	
chinery, cables, etc	25,000	
		37,000
ilding road from the end of the present road at Russel's camp o the am site (20 miles) and about the works (2 miles), 22 miles at $3,000		66,000
gineering expenses and contingencies		72,080
Total cost of dam		538,860

The total capacity of the reservoir being 16,850 acre-feet and the al cost of the dam $538,860, the cost per acre-foot stored would $32.

DINKEY CREEK.

After leaving the North Fork the trail runs almost due west for 15 les, to Russel's camp, on Dinkey Creek, through a flat, open coun- heavily timbered, mostly with fir, until within 3 miles of the ek, when the trail begins to descend from the 7,000-foot level to 6,000-foot level, the sugarpine trees become more plentiful, and asionally, in the beds of the streams, a few sequoias are seen. ikey Creek does not flow through any large basins or meadows. e average fall of the creek is from 25 to 75 feet in 1,000, except ir the headwaters, where the bed is in solid, glaciated granite chan- s, with a fall of from 10 to 25 feet in 1,000.

From Russel's camp west to Ockenden, a distance of 15 miles, there s road built to enable the lumbermen to haul sugarpine shingles to narket at Fresno. There is probably no place in California where ere is more reckless destruction of timber than along this road. either side of it hundreds of fine sugarpines have been cut. Trees o 5 feet in diameter, with the lowest limbs 60 and 70 feet from the ound, have been felled to use perhaps from 6 to 9 feet of the base r shingles, leaving the rest of the timber to rot.

PINE FLAT.

After exploring the drainage basins of Big and Sycamore creeks the party made a detailed survey of the Pine Flat reservoir site (Pl. XII), on the main Kings River, 5 miles below Trimmer, in sections 19, 24, 25, 26, 35, and 36, T. 12 S., R. 24 E., Mount Diablo meridian. The dam site is in section 35. The elevation at the crest of the proposed dam is 600 feet. The bed rock is a blue schist, exposed and bare in the creek bed but seamy on the east side.

The following estimates of the capacity and cost of the reservoir are only preliminary and approximate. Careful examinations should be made before construction is begun. A section of the proposed dam is shown in fig. 2.

Capacity of Pine Flat reservoir.

Height of dam.	Area.	Capacity between contours.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
0	0.0		
20	57.2	572	572
40	187.0	2,442	3,014
60	372.3	5,593	8,607
80	568.7	9,410	18,017
100	912.7	14,814	32,831
120	1,125.0	20,377	53,208
140	1,373.9	24,989	78,197
160	1,642.9	30,168	108,365
180	1,902.4	35,453	143,818
200	2,174.0	40,764	184,582

Estimated cost of dam 200 feet in height.

485,000 cubic yards of rubble masonry at $7	$3
Concrete apron at lower toe of dam, 1,400 feet long, 60 feet wide, and 8 feet thick, 9,333 cubic yards at $9	
Gates, outlet pipes, etc	
Right of way	
Engineering, 2½ per cent	
Contingencies, 7½ per cent	
Total	$

Estimated cost of dam 140 feet in height.

212,000 cubic yards of rubble masonry at $7	$1
Concrete apron at lower toe of dam, 1,100 feet long, 50 feet wide, and 3 feet thick, 6,111 cubic yards at $9	
Gates, outlet pipes, etc	
Right of way	
Engineering	
Contingencies	
Total	1

The cost per acre-foot of water stored is $21.18 for the 200-foot dam and $22.38 for the 140-foot dam. In the case of the 140-foot dam, if the interest on the cost of the works be taken at 6 per cent, taxes at eight-tenths of 1 per cent, and maintenance at $10,000 per annum, the annual charge for operation will be $129,000, or $1 for each acre-foot stored in the reservoir. If 20 per cent of the

d is lost by seepage and evaporation before reaching the lands to rigated, the annual charge per acre-foot delivered will be $2.06. ıe estimates are for a dam made of large blocks of granite bedded hydraulic-cement mortar. It would be 16 feet wide on top, and such side slopes that the resultant of all pressures would fall well in the central third with 10 feet of water passing over the crest. ı the 200-foot dam, the length of which is 1,400 feet, the max- n observed flood, 40,000 second-feet, would have had a depth on est of 4.2 feet; and with the 140-foot dam, which is 1,100 feet

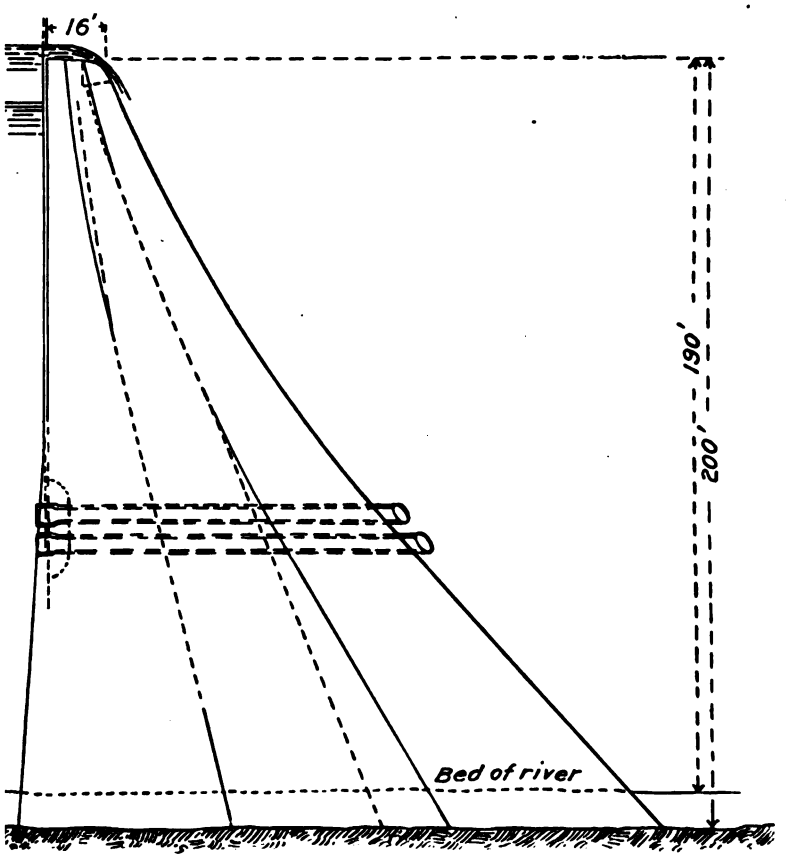


FIG. 2.—Section of proposed Pine Flat weir.

this depth would have been 4.8 feet, assuming that all water ed over the crest. Bed rock is at the surface on the sides and om of the canyon at the dam site. It is a firm blue slate. The ıate is for the entire structure bedded 10 feet deep in the rock. ɔnch of greater depth would have to be sunk and filled with con- at the upper toe. The bed rock should be given most careful y before construction is begun. The estimate includes an apron ɔncrete extending from 50 to 60 feet below the lower toe of the across its entire width, for the protection of the lower toe.

While estimates are given for both a 140-foot and a 200-foot dam, the 140-foot is considered the better for the location.

This reservoir site, although costing nearly double that of Clarks Valley per acre-foot of storage capacity, is of importance in the ultimate development of the lands under Kings River. Being on the main stream it would catch the flood discharge up to its full capacity. It is just above the diversions of all irrigation canals and above the proposed diversion canal line to the Clarks Valley reservoir site which is not on the river. (See map of drainage basin, Pl. I.) Thus it could be used as a regulator or governor to the river for the conveyance of water to the Clarks Valley reservoir, and, after that has been filled, for the holding of the surplus water. For example, it is obvious that so great a volume as passed in January, 1896 (see discharge diagram, Pl. VII), when on the 18th the discharge increased to 8,500 second-feet and on the 11th to 11,020 second-feet, must be in large part lost in passing the headworks of the diversion canal (capacity 1,250 second-feet) to the Clarks Valley site and the irrigation canal (combined capacity of 4,000 second-feet); but with this large regulator on the main stream all of the water would be saved and gradually discharged into the Clarks Valley canal, leaving the Pine Flat reservoir empty and in readiness for the next flood. The indirect benefit of the Pine Flat reservoir as a governor would be as great as its direct utility as a storage reservoir, and the site should be controlled by the irrigation interests of Kings River.

Discharge of Kings River, showing amounts of water available for storage.[a]

Seasonal year, November to October, inclusive.	Total seasonal discharge Nov. 1 to Oct. 31.	Total seasonal diversion Nov. 1 to Oct. 31.[b]	Diversion Nov. 1 to Feb. 28.[c]	Summer.	Irrigation diversion Mar. 1 to Oct. 31.[d]	Surplus after summer diversion Mar. 1 to Oct. 31
	Acre-feet.	*Acre-feet.*	*Acre-feet.*		*Acre-feet.*	*Acre-feet.*
1895-96	1,852,425	1,070,900	134,152	1896	936,748	915,152
1896-97	2,088,924	1,198,691	168,846	1897	1,029,845	1,059,079
1897-98	876,079	820,522	164,220	1898	656,302	219,778
1898-99	1,227,217	996,307	102,348	1899	893,959	333,348
1899-1900[e]	1,281,051	1,032,158	214,527	1900	817,631	468,527
Mean	1,465,139	1,023,716	156,819		866,897	598,819

[a] From gagings of the United States Geological Survey at Red Mountain station.
[b] This assumes a diversion from the river of 4,000 second-feet (the full capacity of the irrigation canals) between March 1 and October 31 and 2,000 second-feet between November 1 and February 28, when the water in the river is available.
[c] Total flow of river up to 2,000 second-feet.
[d] Total flow of river up to 4,000 second-feet.
[e] The season of 1900-01 was one of abundant supply.

It is believed that if an ample summer supply is assured midwinter irrigation will be largely if not entirely discontinued.

By reference to the table on page 21, giving a summary of the stream measurements by the California State engineering department and by the United States Geological Survey, it will be seen that during the period of observation of ten years the season of 1897–98 (summer 1898) had the lowest flow, the season of 1878–79 being next, with a discharge of 397,886 acre-feet more than in the former season.

twenty-three year rainfall record at Fresno (see table on page 16) shows the year of lowest precipitation to have been 1878–79, when 4.87 inches fell, the next lowest being the season of 1897–98, when 4.95 inches were observed. The official rainfall record at Sacramento (see table on page 16) shows the lowest precipitation during the period over which the record extends (1877–1900) to have been in the season of 1897–98, the amount being 10.50 inches. It will be noted that stream measurements have been made during the years of lowest observed rainfall at Fresno, and that both five-year periods (page 21) were during cycles of low rainfall. In fact not one of these years was a wet year. An old rainfall record kept at Sacramento by Dr. Thomas Logan since 1849 shows dry-year records as follows: 1850–51, 4.71 inches; 1863–64, 7.87 inches; 1870–71, 8.47 inches. The Central Pacific Railway shows a record of 8.95 inches in 1876–77. All of these are below the observed rainfall of 10.50 inches at Sacramento in 1897–98. It is not believed that a standard rain gage was available at Sacramento in the winter of 1850, and the record of 4.71 inches is so much below any other record during the fifty-one years of observation that it may be seriously questioned.

In view of all the facts, the following conclusions seem justifiable:

(1) The observed flow of Kings River for the season of 1897–98 may be assumed to be a very low discharge but not an absolute minimum. For the purpose of this report it may, however, be taken as a minimum.

(2) These minimum years probably will occur about once in ten years.

(3) There will be enough water during November to February, inclusive, in excess of the 4,000 second-feet summer diversions (March to October), to fill the Pine Flat reservoir every year if the dam is built to a height of 140 feet, capacity 78,197 acre-feet.

(4) In nine out of ten years there will be enough water to supply all winter and summer irrigation on the present basis and leave the Pine Flat reservoir full for use after July 1.

(5) The water that would be stored in the Pine Flat reservoir is water that otherwise would be lost.

(6) The Pine Flat reservoir would irrigate the most valuable lands in Fresno and Tulare counties, now dry and unproductive.

(7) The cost of reservoir would be $22.38 per acre-foot stored, and the earning powers of the reservoir many times that amount.

The available water supply is discussed further in connection with the Clarks Valley reservoir site (pages 39 to 42).

CLARKS VALLEY.

After completing the work in the drainage basin of Kings River a reconnaissance of the foothills was made, extending as far as the mouth of San Joaquin River on the northwest and on the southeast to 15 miles from the mouth of Kings River, with a view to finding, if possible, a storage basin to which the flood waters of the river could

be diverted. The only basin found was Clarks Valley. This res voir site is in Fresno County, 16 miles east of Sanger. The stage ro from Sanger to Millwood runs from west to east through the center the site. In elevation it commands all of the canals diverting wa from Kings River except the Gould canal, and is within 2 or 3 mi of the intake of most of those systems. It is about 1½ miles dist from the main drainage line on Kings River opposite the reserv and approximately 100 feet higher. It is proposed to fill this res voir, by means of a diversion canal, with the flood and excess wat of Kings River. The diversion canal would be 53,600 feet in leng The headworks would be above the mouth of Mill Creek and at t Pine Flat dam site.

One rather peculiar feature of Clarks Valley is that three isolat buttes partially inclose a portion of San Joaquin Valley betwe themselves and the foothills of the main range. To make the res voir complete the openings between these hills will have to be clo by three separate dams. The arroyo of Wahtoke Creek, which pas through the center of the reservoir site, is about 75 feet wide and feet deep. The maximum height of dam is considered from the b tom of this arroyo, which gives a somewhat exaggerated idea of (See Pl. XIII.) The location will permit the construction of a d 105 feet maximum height, which will impound water to a maxim depth of 100 feet. For the purpose of this report it was decided give estimates on the cost of building a dam of 105 feet maxim height and also one of 85 feet maximum height, to impound wate maximum depths of 100 feet and 80 feet, respectively. The heig of the two smaller dams will depend upon the height of the large central dam, as shown in the tables on pages 35 and 37.

The drainage area of the basin of Wahtoke Creek, in which Clarks Valley site is located, is 33 square miles. The average ele tion of the drainage basin is 1,000 feet. Assuming the average ann rainfall to be 20 inches and the run-off 12 per cent, we have 4, acre-feet as the amount of water available for storage from the l drainage basin. The assumed elevation at the base of the dam 400 feet, which is the elevation used for maps and calculations. sea level 29 feet should be added. The capacity of the reservoi different heights of the water is given in the following table. elevation of the outlet is 420 feet.

Capacity of Clarks Valley reservoir site.

Maximum depth of water.	Area.	Capacity of section.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
0	0.0	.....	.....
20	248.3	Below outlet.	.....
40	1,146.0	13,943	13,943
60	2,592.2	37,382	51,325
80	4,325.2	69,174	120,499
100	5,344.5	96,697	217,196

CONTOUR MAP OF CLARKS VALLEY RESERVOIR SITE AND PROPOSED DIVERSION CANAL.

The dams would be of earth, the material in each case being near enough to the dam site to readily be transported by cables or other mechanical devices. A reddish clay containing about 10 per cent of coarse gravel and some sand can be used.

105-FOOT DAM.

The following quantities are for a large dam 105 feet high, 20 feet wide on top, with a slope of 2½ to 1 on the upstream side and 1½ to 1 on the lower side.[a] The maximum depth of water will be 100 feet and the storage capacity 217,196 acre-feet.

Quantities of material for 105-foot dam and the two side structures.

Dam.	Length on crest.	Greatest depth.	Earth.
	Feet.	*Feet.*	*Cu. yds.*
No. 1	3,370	83	885,020
No. 2	8,865	105	5,272,990
No. 3	2,880	65	556,460
Total			6,714,470

At 20 cents per cubic yard the cost of the dams would be $1,342,895.

To fill the reservoir to the 100-foot level (217,196 acre-feet) a conduit with a capacity of 1,250 cubic feet per second would be required. The total length of this conduit, from the headworks on Kings River to the reservoir, would be 53,600 lineal feet, as follows: 7,000 feet of tunnel into reservoir, 3,600 feet of cutting at entrance and discharge of tunnel, and 43,000 feet of canal partly in rock.

Intake tunnel.—The elevation of the bottom of the inlet tunnel at its reservoir end is fixed at 20 feet above the maximum flow line for the larger (105-foot) dam, so as to permit raising the dam in the future. The elevation of the intake at Kings River is estimated at 558.5 feet. The elevation of the Pine Flat dam site is approximately 600 feet. The cross section of the inlet tunnel will be 10½ feet by 12 feet, and the velocity of the water will be 10 feet per second. The tunnel will be in granite. The estimated cost, unlined, is $12 per running foot, or a total of $84,000, exclusive of the tunnel approaches, the cost of which will be as follows:

Cutting at entrance to tunnel:	
13,700 cubic yards of rock at $1	$13,700
27,410 cubic yards of earth at $0.20	5,482
Cutting at discharge end of tunnel:	
10,072 cubic yards of rock at $1	10,072
5,036 cubic yards of earth at $0.20	1,007
Total	30,261

[a] This section is assumed for the purpose of this estimate and is not necessarily final. This important matter should be most carefully considered before construction is begun and determined only after detailed examination of the material available and of the foundations.

Diversion canal.—The canal will have a capacity of 1,250 cubic feet per second and a grade of 1.056 feet to the mile in earth and loose rock and 3.168 feet to the mile in solid rock section. The bottom width will be 17 feet and the cost as follows:

Earth, 362,000 cubic yards at $0.20	$72,4
Loose rock, 401,505 cubic yards at $0.50	200,7
Solid rock, 78,600 cubic yards at $1	78,6
Total	351,7

Sections of the canal in earth and loose rock and in solid rock are shown in Pl. XIV.

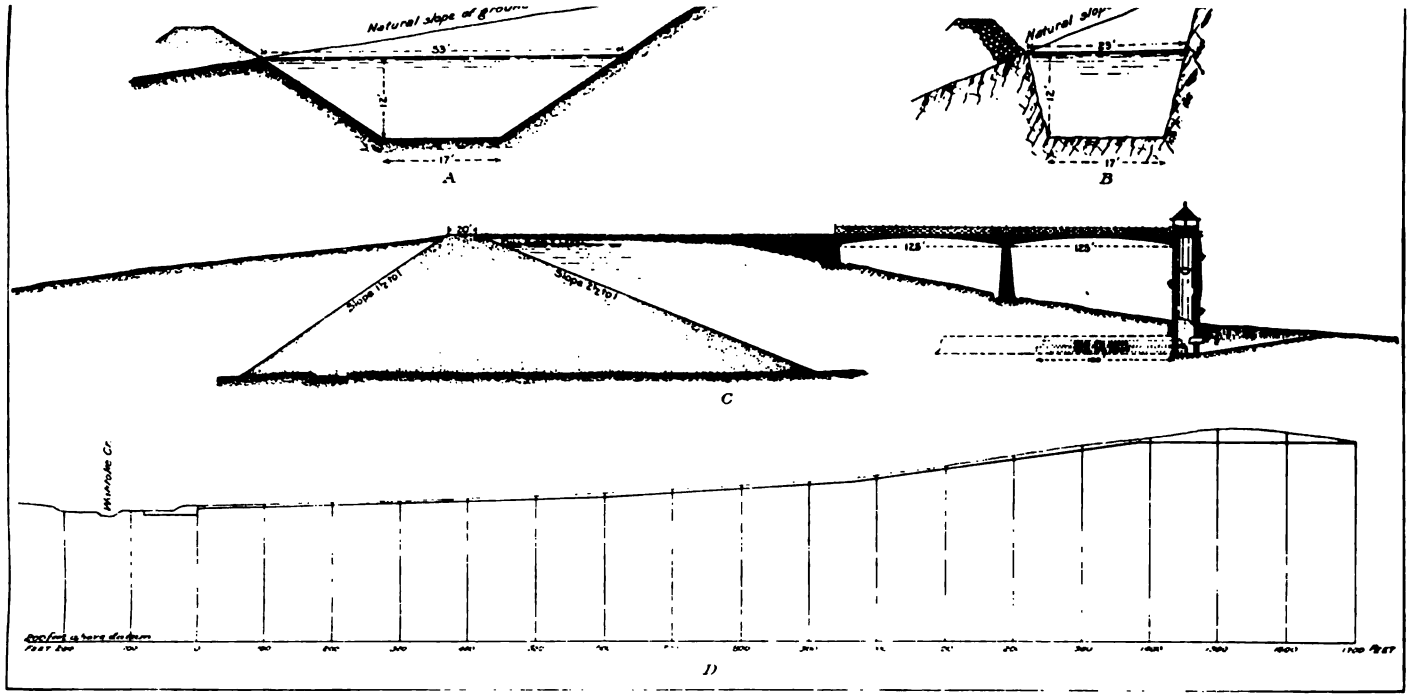
Spillway at dam No. 2.—This spillway will be 100 feet wide, with a capacity of 1,698 cubic feet per second and a depth of water of 3 feet. The cost will be as follows:

25,886 cubic yards of rock at $1	$25,88
16,650 cubic yards of earth at $0.25	4,16
Concrete walls and foundations in earth	24,72
Water cushion at foot of spillway	3,00
Total	57,76

The spillway will have to provide for floods in the local drainage basin (53 square miles) of Wahtoke Creek only. The area of the reservoir at the 100-foot level is 5,344 acres, and if there were no spillway it would require a flood of 2,672 second-feet for one day to raise the water level 1 foot. The top of the dam will be 5 feet above the spillway. The west end of dam No. 2 is shown in plan and section in Pl. XV, *A*, and a longitudinal section of the spillway in Pl. XIV, *D*.

Outlet tunnel, tower, gates, etc.—Pl. XV, *B*, shows a cross section and a longitudinal section of the outlet channel, and Pl. XIV, *C*, combined sections with tower. The cost of the outlet tunnel, tower gates, etc., is as follows:

Outlet tunnel, 1,100 lineal feet, 10 feet by 12 feet clear section, cement lined, at $12		$13,2
Cutting approach to tower:		
1,381 cubic yards of rock at $1	$1,381	
2,762 cubic yards of earth at $0.25	690	
Cutting at discharge end of tunnel:		
741 cubic yards of rock at $1	741	
1,481 cubic yards of earth at $0.25	370	
		3,1
Concrete valve tower, 12 feet inside diameter and 85 feet high	3,352	
Concrete dam, 100 feet long, connecting tower with tunnel	2,782	
Four pipes through concrete dam, each 48 inches in diameter by 100 feet long, with gates attached, at $1,500	6,000	
Tower valves and appliances, seven at $500	3,500	
House on top of tower	500	
Concrete and iron footbridge to tower, two spans of 125 feet each	5,000	
Concrete and iron footbridge over spillway, 100 feet	2,000	
		23,1
Total		39,5



DETAILS OF PROPOSED RESERVOIR IN CLARKS VALLEY

A, Section of canal in earth and loose rock; *B*, section of canal in solid rock; *C*, combined sections, showing tower; *D*, longitudinal section of spillway

Headworks on Kings River.—The estimated cost of diverting dam, [illegible] box, gates, etc., is $25,000.

Summary of cost.—Summarizing, the cost of the works with large [illegible] 105 feet high, storing 217,196 acre-feet, is as follows:

[illegible] Nos. 1, 2, and 3	$1,342,895
[illegible]et tunnel, or feed conduit	84,000
[illegible]tting at each end of inlet tunnel	30,261
[illegible]nal between intake and tunnel approach	351,750
[illegible]llway at dam No. 2	57,780
[illegible]tlet tunnel	13,200
[illegible]tting at each end of outlet tunnel	3,182
Valve tower, gates, etc	23,134
[illegible]take works on Kings River	25,000
[illegible]ght of way	75,000
	2,006,202
[illegible]gineering and contingencies, 10 per cent	200,620
Total	2,206,822

The cost per acre-foot of water stored is $10.15.

Annual cost per acre-foot of water delivered.—Figuring the interest [illegible] 6 per cent of the cost of the works ($2,206,822), the taxes at eight-[illegible]nths of 1 per cent of the cost, and maintenance for the reservoir [illegible]d diversion canal at $10,000 per annum, we have an annual charge [illegible]gainst the plant of $160,064. We have found that the evapora-[illegible]on would amount to 3½ per cent of the entire storage capacity of [illegible]he larger reservoir; but if we take the evaporation at 5 per cent [illegible]nd the seepage in the canal at 15 per cent we have 173,757 acre-feet [illegible]vailable for delivery. This divided into the annual charge of $160,064 gives an annual cost per acre-foot of water delivered from [illegible]he reservoir to the lands of $0.92.

85-FOOT DAM.

The following quantities are for a large dam 85 feet high, 20 feet wide on top, with a slope of 2½ to 1 on the upstream side and a slope of 1½ to 1 on the downstream side. The maximum depth of water will be 80 feet and the storage capacity 120,499 acre-feet.

Quantities of material for 85-foot dam and the two side structures.

Dam.	Length on crest.	Greatest depth.	Earth.
	Feet.	*Feet.*	*Cu. yds.*
[illegible]o. 1	3,100	63	504,189
[illegible]o. 2	8,640	85	3,085,171
[illegible]o. 3	2,585	43	248,468
Total			3,837,828

At 20 cents per cubic yard the cost of the dams would be $767,565.

To fill the reservoir to the 80-foot level (120,499 acre-feet) a conduit with a capacity of at least 525 cubic feet per second would be required. The total length of the conduit from the headworks on Kings River to the reservoir would be 53,600 feet, divided the same as for the 105-foot dam, i. e., 7,000 feet of tunnel, 3,600 feet of cutting at entrance and exit of tunnel, and 43,000 feet of diversion canal.

Intake tunnel.—The feed tunnel will be of the same dimensions and grade and in the same location as for the 105-foot dam—7,000 lineal feet in solid rock, unlined, at $12 per lineal foot, $84,000, plus the cost of cutting at the entrances, $24,790. The elevation of the lower end of the inlet tunnel is fixed at 520 feet, the same as for the larger reservoir, so as to permit increasing the height of the dam in the future, if desired. The elevation of the intake is taken at 558.5 feet.

Diversion canal.—The canal will have a capacity of 525 cubic feet per second and a grade of 1.584 feet to the mile in earth and loose rock and 4.224 feet to the mile in solid rock section. The bottom width will be 10 feet and the cost as follows:

151,330 cubic yards of earth at $0.20	$30,266
30,840 cubic yards of rock at $1	30,840
166,140 cubic yards of loose rock at $0.50	83,070
Total	144,176

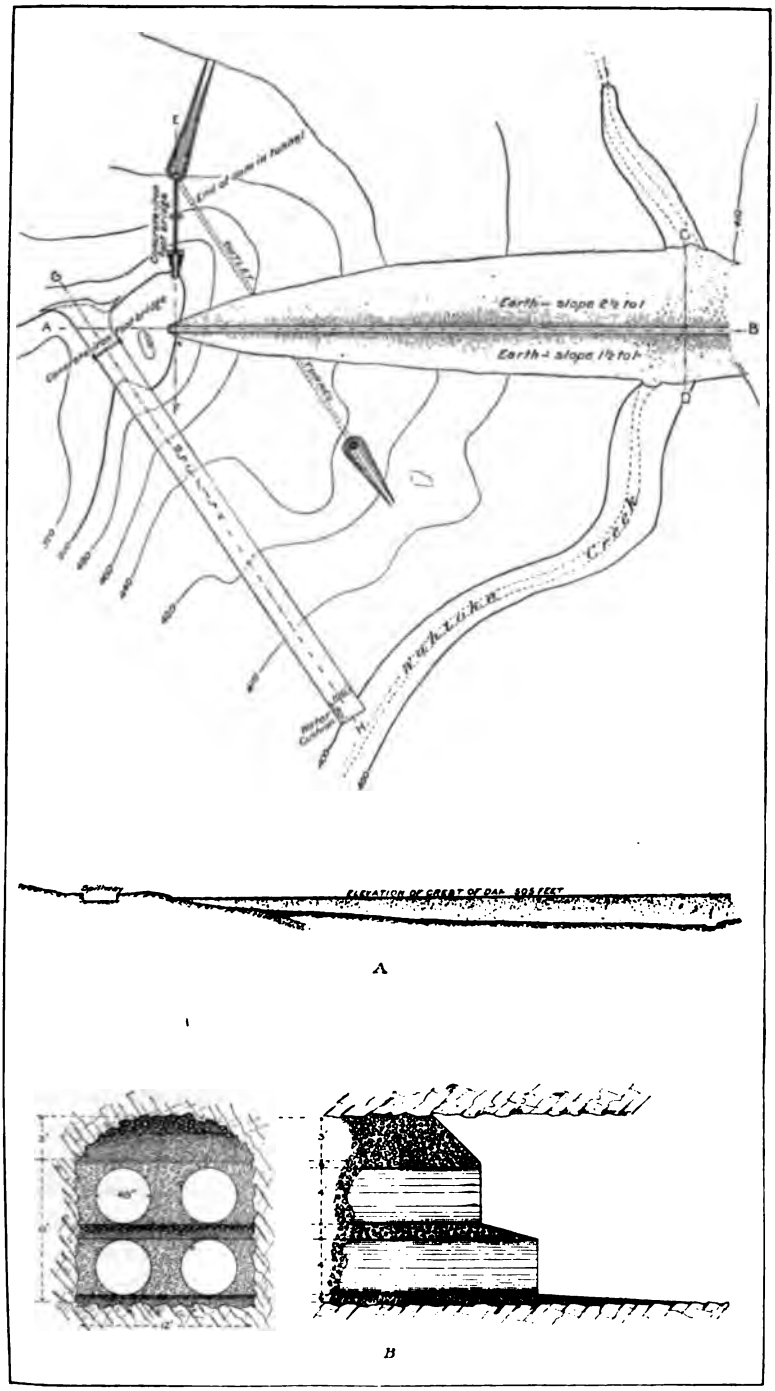
Spillway at dam No. 2.—The spillway will be 100 feet wide, with a capacity of 940 cubic feet per second and a depth of water of 2 feet. The cost will be as follows:

13,625 cubic yards of earth at $0.25	$3,406
27,251 cubic yards of rock at $1	27,251
Foundation in earth, 3,000 cubic yards at $0.50	1,500
Concrete in walls and bottom, 3,000 cubic yards at $6	18,000
Total	50,157

Outlet tunnel, tower, gates, etc.—The cost of the outlet tunnel and of cutting approach to tower and at discharge end of tunnel would be practically the same as for the 105-foot dam. The estimate of cost of tower, gates, etc., is as follows:

Concrete valve tower, 12 feet inside diameter and 85 feet high	$3,352
Concrete dam 100 feet long, connecting tower with tunnel	2,782
Four pipes through concrete dam, each 48 inches diameter by 100 feet long, with gates attached, at $1,500	6,000
Tower valves and appliances, seven at $500	3,500
House on top of tower	500
Concrete and iron footbridge to tower, two spans of 125 feet each	5,000
Concrete and iron footbridge over spillway, 100 feet	2,000
Total	23,134

Headworks on Kings River.—The estimated cost of diverting dam *sand box, gates,* etc., is the same as for the 105-foot dam, viz, $25,000



DETAILS OF PROPOSED RESERVOIR IN CLARKS VALLEY.

A, Plan and section of west end of dam No. 2; B, cross section and longitudinal section of outlet tunnel.

Summary of cost.—Summarizing, the cost of the works with large dam 85 feet high, storing 120,499 acre-feet, is as follows:

Dams Nos. 1, 2, and 3	$767,566
Feed tunnel	84,000
Cutting at each end of inlet tunnel	24,790
Diversion canal between intake and tunnel approach	144,176
Spillway at dam No. 2	50,157
Outlet tunnel	13,200
Cutting approaches at each end of outlet tunnel	3,000
Valve tower, gates, etc	23,134
Headworks on Kings River	25,000
Right of way	75,000
	1,210,023
Engineering and contingencies, 10 per cent	121,002
Total	1,331,025

The cost per acre-foot of water stored is $11.05.

Annual cost per acre-foot of water delivered.—Figuring the interest at 6 per cent of the cost of the works ($1,331,025), the taxes at eighths of 1 per cent of the cost, and maintenance for the reservoir and diversion canal at $10,000 per annum, we have an annual charge against the plant of $100,510. We have found that the evaporation would amount to 4.7 per cent of the entire storage capacity of the reservoir, but if we take the evaporation and seepage at 20 per cent, as for the 105-foot dam, it would leave 96,399 acre-feet available for delivery. This divided into the annual charge of $100,510 gives an annual cost per acre-foot of water delivered from the reservoir of $1.04.

WATER SUPPLY.

Assuming the annual rainfall to be 20 inches over the 33 square miles of drainage area of Wahtoke Creek, and the run-off to be 12 per cent, we have 4,224 acre-feet. The storage capacity of the 105-foot dam is 217,196 acre-feet. This, less the 4,224 acre-feet from rainfall on the local drainage basin, gives 212,972 acre-feet of water to be brought by diversion conduit from Kings River. In order to determine whether a canal with a capacity of 1,250 second-feet would fill the reservoir, the following assumptions have been made:

(1) That all of the water in Kings River up to the capacity of the canal (1,250 second-feet) can be diverted during the months of November, December, January, and February.

(2) That the combined capacity of the canals diverting water from the river during the remaining months is 4,000 second-feet, and the surplus above that amount is available, to 5,250 second-feet, for storage.

The following statement, based on the daily discharge of the river at the Red Mountain gaging station of the United States Geological Survey, which is practically at the proposed point of diversion, shows the amounts of water which could have been diverted with a dam 105

feet high and a canal of 1,250 second-feet capacity, under the foregoing conditions.

Available water supply, in acre-feet, of Clarks Valley reservoir site with 105-foot dam

Month.	Season 1895–96.	Season 1896–97.	Season 1897–98.	Season 1898–99.	Season 1899–1900.
November	20,838	31,989	36,935	13,741	37,8
December	20,067	30,501	45,438	18,929	48,2
January	47,742	26,841	31,312	31,395	66,4
February	47,308	67,855	39,105	36,575	41,4
March	3,993	808	.....	5,444	.....
April	3,564	44,368	25,404	39,497	.....
May	30,393	76,725	12,474	8,890	46,1
June	74,072	38,662	.....	47,144	41,7
July	26,758	79	.....	.....	.....
Total	274,495	317,918	190,668	201,595	281,9

* The season of 1900–01 was one of abundant supply.

Taking the season of least available flow (1897–98) we have 190,6(
acre-feet. If we add to this the amount of water available from th
local drainage basin (4,224 acre-feet) we have a total of 194,892. Thi
is 22,304 acre-feet, or 9½ per cent, less than the maximum capacity of th
reservoir for a year of extreme drought, which is not likely to occur bu
once in ten years. For the season of 1898–99 the amounts would b
201,595 acre-feet from the river and 4,224 acre-feet of rainfall store
giving a total of 205,819 acre-feet, or 11,377 acre-feet less than th
maximum storage capacity. That year also was one of drought. Fo
the remaining three seasons of observation the flow is more than su
ficient. The rainfall records at Fresno indicate the last five years t
have been the driest observed since 1877, and it is believed that the
may be accepted as a minimum.

In connection with the foregoing figures there is an important poir
to be considered, viz: If the people who now are using the flow of th
river in March and October to flood their lands could be assured of
sufficient quantity of water later in the season, part of the flow of th
river for those months could be diverted to the reservoir, and thu
the reservoir be filled to its maximum capacity each year. The follow
ing table shows the quantities of water that could have been diverte
from Kings River by a canal of maximum capacity of 525 second-fe
and an 85-foot dam, under conditions similar to those prevailing f
the 105-foot dam:

Available water supply, in acre-feet, of Clarks Valley reservoir site with 85-foot da

Month.	Season 1895–96.	Season 1896–97.	Season 1897–98.	Season 1898–99.	Seas 1899–1
November	19,394	28,403	28,086	13,741	28,
December	20,067	30,444	32,224	17,494	30,
January	28,185	26,552	30,650	28,225	32,
February	30,145	29,106	28,819	28,453	29,
March	2,079	808	.....	2,673	.....
April	3,118	30,638	12,929	18,572	.....
May	18,711	32,224	6,049	7,286	20,
June	31,185	16,632	.....	22,879	21,
July	12,432	79	.....	.....	.....
Total	165,316	184,886	138,757	139,323	162,

Using the season of minimum observed flow (1897–98) we have 138,757 acre-feet available flow from the river, which with the 4,224 acre-feet from the local basin gives a total of 142,981 acre-feet, or 22,482 acre-feet more than the maximum storage capacity of the reservoir.

If the Pine Flat and the Clarks Valley dams are both built the following tables will show the available supply. These tables (determined by planimeter from the diagrams of stream flow) are based (1) upon a diversion by the irrigation canals of water to their full capacity, viz, 4,000 second-feet, from March 1 to October 31, and (2) upon the fact that with the regulating reservoir at Pine Flat the Clarks Valley reservoir could have been completely filled, to either the 100-foot or the 80-foot level, each year.

The entire capacity of the Clarks Valley reservoir less the supply from the local drainage basin (4,224 acre-feet) is therefore also deducted from the seasonal flow of the river each year. All of the water remaining in the river is considered available for storage at Pine Flat. It is reasonably certain that both reservoirs would have been completely filled during the five-year period of observation by the State engineering department, i. e., 1878 to 1883. It must be remembered that the ten years for which we have records were below the average in rainfall and run-off. The year 1897–98 may be taken as the minimum of a ten-year period of low rainfall. The season of 1900–1901 is now (June 1, 1901) far enough advanced to show that the supply for this year would have been more than ample to fill both reservoirs. The table shows that with the larger dam at Clarks Valley (the 105-foot) there would have been one year out of the eleven that the Pine Flat reservoir could not have been filled.

Available water supply, in acre-feet, for 140-foot dam at Pine Flat reservoir site with 105-foot dam at Clarks Valley reservoir site.

Season Nov. 1 to Oct. 31.	Total discharge of river.	Clarks Valley diversion.	Irrigation diversion Mar. 1 to Oct. 31.	Available for Pine Flat reservoir (capacity, 178,197 acre-feet).
1895-96	1,852,425	212,972	936,749	703,704
1896-97	2,088,924	212,972	1,029,845	846,107
1897-98	876,079	212,972	656,302	6,805
1898-99	1,227,217	212,972	893,959	120,286
1899-1900	1,281,051	212,972	817,631	250,448
Five-year mean	1,465,139	212,972	806,897	385,470

The foregoing table shows the possibility of having used 79 per cent of the average flow of Kings River during the last five years.

Available water supply, in acre-feet, for 140-foot dam at Pine Flat reservoir site with 85-foot dam at Clarks Valley reservoir site.

Season Nov. 1 to Oct. 31.	Total discharge of river.	Clarks Valley diversion.	Irrigation diversion Mar. 1 to Oct. 31.	Available for Pine Flat reservoir (capacity, 78,197 acre-feet).
1895–96	1,852,425	116,275	936,749	800,401
1896–97	2,088,924	116,275	1,020,845	952,804
1897–98	876,079	116,275	656,302	103,502
1898–99	1,227,217	116,275	893,959	216,983
1899–1900	1,281,051	116,275	817,631	347,145
Five-year mean	1,465,139	116,275	866,897	482,167

The foregoing table shows that both reservoirs could have been filled every year during the period given.

Normally the reservoir at Clarks Valley, as previously stated, would be full at the end of June and empty at the end of September. The period during which evaporation will have to be considered is the months of July, August, and September. The evaporation observations given herein show that the mean evaporation during those months is 1.89 feet each year. The total storage capacity of the reservoir at the 100-foot level is 217,196 acre-feet; the area at the 100-foot level is 5,344 acres and at the 80-foot level 4,325 acres. For the purpose of this estimate the average area for the larger reservoir exposed to evaporation may be considered as 4,000 acres, losing in depth 1.89 feet each year, or 7,560 acre-feet, which is 3½ per cent of the total storage capacity of the reservoir. With the smaller dam the evaporation would amount to 4.7 per cent, or 5,670 acre-feet.

SPILLWAY.

The Clarks Valley reservoir will be almost entirely free from attacks of floods, as the local drainage basin contains only 33 square miles, and its annual discharge will probably be equal to a depth of about 1 foot in the reservoir at the 100-foot level. The diversion canal, having a capacity of 1,250 second-feet, or 2,500 acre-feet, per day, would require two days' flow to raise the water in the reservoir 1 foot in height when it stands at the 100-foot level. The capacity of the outlet from the reservoir will be 1,280 cubic feet per second (greater than that of the intake), with 10 feet head on the valves. This will be in addition to the capacity of the spillway.

The months during which the maximum amount of water is available for storage from Kings River are May and June. This is after the expiration of the rainy season, and it will be the discharge of the diversion canal during these two months that will finally fill the reservoir each year. Since 1877 the greatest rainfall that has occurred

in May was 1.97 inches, in 1900. On this basis the water that fell in the local drainage basin of Wahtoke Creek would amount to 3,380 acre-feet. The area of the reservoir at the 100-foot level is 5,344 acres.

Since 1877 there have been only three occasions when rain has fallen at Fresno during the month of June, the greatest precipitation for that month being 1.29 inches, in 1884. It is therefore reasonable to assume that during the time the reservoir is full the local drainage basin can never deliver a volume of water sufficient to raise the level of a full reservoir more than 1 foot, even if the discharge gate and the spillway are both closed. It is proposed to make the elevation of the spillway 7 feet below the top of the dam and to maintain the water in the reservoir at that height during the entire rainy season. After the expiration of the rainy season—say the first of June—it would be safe to place flashboards in the spillway, so as to store 2 feet more of water. This would bring the water to the maximum depth of 100 feet, would add about 10,000 acre-feet to the storage capacity, and would still leave the top of the reservoir 5 feet above the level of the water. If it should be considered desirable to increase the interval between the water level and the top of the dam it could most economically be done by increasing the height of the dam 2 or 3 feet on slopes of 1½ to 1 on each side. It will be remembered that there probably would not be more than two weeks intervening between the complete filling of the reservoir and the beginning of the discharge from it.

A longitudinal section of the spillway proposed is shown in Pl. XIV, *D*.

RESERVOIR SURVEYS.

On June 19 the party reported at Sanger, Fresno County, on the Southern Pacific Railroad, where camp equipment was received. A pack train of 5 mules and 4 saddle horses was purchased in the neighborhood, at an average cost of $40 per animal. The party, which was in charge of Mr. H. E. Green, consisted of a topographer, two rodmen, a packer, and a cook. After July 12 one rodman was dispensed with, reducing the party to four.

On June 22 the party left Sanger, at an elevation of 370 feet, and started for Millwood. Following the county road and crossing to the south of Kings River near Centerville, the foothills were reached about 16 miles from Sanger, the road traversing the lower Clarks Valley reservoir site. From Clarks Valley to Millwood the road ascends 4,710 feet in a distance of 30 miles, the elevation of Millwood being 5,210 feet, aneroid measurement. From Millwood the party went into camp at Long Meadow, where the first survey work was done on the Long Meadow reservoir site.

LONG MEADOW.

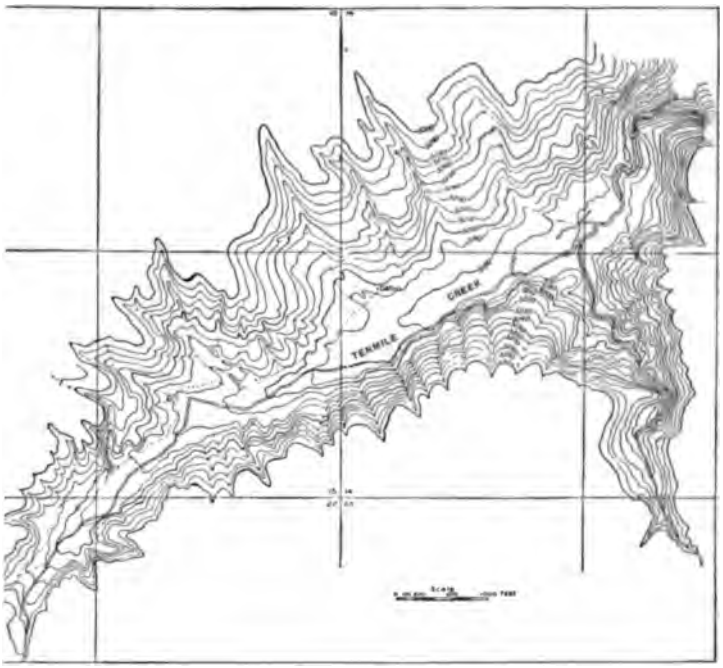
Long Meadow can be reached in 11 miles from Millwood by taking the Sanger Lumber Company's wagon road to their sawmill, a distance of 6 miles, and then following the trail for 5 miles, crossing the divide at an elevation of 6,770 feet; or it can be reached without surmounting such an elevation by keeping the wagon road via the sawmill to Converse Meadow, 12 miles distant and at an elevation of 5,900 feet, and following the trail for 2 miles across the low divide separating Converse Meadow from Long Meadow.

Long Meadow, which is at an elevation of 5,200 feet, is on Tenmile Creek, about 4 miles above its junction with Kings River, which junction is less than a quarter of a mile west of the junction of the Middle and South forks of the river. The reservoir and dam sites are in secs. 14, 15, 22, and 23, T. 13 S., R. 28 E., Mount Diablo base and meridian. The land is owned by the Sanger Lumber Company and is well timbered with pine. The dam site is in the northeast quarter of sec. 14, T. 13 S., R. 28 E. The average elevation of the watershed of the meadow or valley is 7,000 feet above sea level, and the supply of water will be largely from melting snow in the spring. Contour maps of the reservoir and dam sites are shown in Pl. XVI.

The drainage area tributary to Long Meadow is estimated at 25 square miles. The estimated mean rainfall is 45.3 inches, making the run-off per square mile 900 acre-feet, or $900 \times 25 = 22{,}500$ acre-feet per year. If we assume a rainfall of 40 inches and a run-off of 50 per cent the average yield would be 26,560 acre-feet per year; or if we assume 2 second-feet run-off per square mile we have 50 second-feet, or 100 acre-feet, per day, which is equal to 36,500 acre-feet per year. The capacity of the reservoir with a dam 170 feet high is 25,334 acre-feet.

Owing to the heavy grade to be surmounted in hauling material from the Southern Pacific Railroad at Sanger via Millwood, which is the shortest approach, a loose rock-fill dam with plank face is considered the most economical. Freight from Sanger to Millwood (45 miles) costs $9 per ton of 2,000 pounds, or 45 cents per hundred pounds. From Millwood freight would go, by the mill road already mentioned, 12 miles to Converse Meadow, elevation 5,900 feet. From there a road would have to be graded over the low divide separating Converse Meadow from Long Meadow. This can be done, with easy gradients, at an estimated length of 4 miles. The proposed method of building the dam is by the use of two Lidgerwood cables, one on the axis of the dam, with traveling towers, and the other crossing the dam, working two quarries, one above and one below the dam site.

The bed rock at the proposed dam site is granite, solid and bare in the creek bed but seamy on the north side of the canyon. It is in



A. CONTOUR MAP OF LONG MEADOW RESERVOIR SITE.

B. CONTOUR MAP OF LONG MEADOW DAM SITE.

trata from 5 to 10 feet thick, with a dip to the south of about 30 legrees. The south side of the canyon will require stripping, probbly 8 or 10 feet. It was impossible to carry tools to determine the lepth to bed rock, and the estimate of the amount of stripping required is obtained from surface indications. A view of the dam site n the north side of the creek is shown in Pl. XVII, *A*.

Data regarding Long Meadow dam.

levation at base of dam	feet	5,130
levation of floor of wasteway	do	5,290
levation of crest of dam	do	5,300
levation of outlet	do	5,150
eight of dam	do	170
rainage area	square miles	25
un-off, estimated	acre-feet	22,500
apacity of reservoir below wasteway	do	25,334
apacity of reservoir at crest level	do	30,033

Following is the preliminary estimate of cost:

Estimate of cost of loose rock-fill dam at Long Meadow.

oose rock, 673,000 cubic yards at $0.75	$504,750
lank face, area 144,800 square feet:	
Two layers of 3-inch plank on lower half of face, 324,000 feet, B. M., at $30	9,720
Two layers of 2-inch plank on upper half of face, 360,000 feet, B. M., at $30	10,800
ills, 12 inches by 12 inches, spaced 4 feet between centers, equal to a layer of 3-inch timber over entire surface, 432,000 feet, B. M., at $30	12,960
abor on plank face	6,000
'asteway, 50-foot bottom width, slopes ½ to 1, 6 feet depth of water, capacity 2,400 second-feet, length 400 feet, lined with cement:	
Excavation, 15,000 cubic yards of rock at $1	15,000
Cement lining, 3,000 square yards (200 barrels of cement at $8, $1,600; labor, 3,000 square yards at $0.10, $300)	1,900
ıtlet tunnel in solid rock, cement lined, 4 feet by 6 feet, arched top and bottom, 500 lineal feet at $10	5,000
ıwer, including house and bridge, valves, gates, etc	8,000
achinery and cable (75-horsepower engine, 2½-inch cable, two traveling towers to handle 10 tons)	26,000
ad from Converse Meadow to Long Meadow (4 miles) and to cable towers and around works (2 miles), 6 miles at $3,000	18,000
learing reservoir, 500 acres at $5	2,500
	620,630
ngineering and contingencies, 15 per cent	93,085
Total	718,715

The cost per acre-foot of water stored is $28. Plan, elevation, and maximum cross section of the proposed dam are shown in Pl. XVIII.

The cost of a concrete dam at this site would be much greater than that of a rock-fill dam. The estimate is as follows:

Estimate of cost of concrete dam at Long Meadow.

171,000 cubic yards of masonry at $10	$1,710,000
Wasteway, 50 feet by 10 feet	16,900
Outlet tunnel, 4 feet by 6 feet	5,000
Tower, etc	8,000
Machinery and cable	26,000
Roads	18,000
Clearing reservoir	2,500
	1,786,400
Engineering and contingencies	100,000
Total	1,886,400

With a concrete dam the cost per acre-foot of water stored is $74, against $28 with a loose rock-fill dam.

EAST LAKE.

From Long Meadow the party moved to East Lake, where the next survey work was done in July. This lake is about 2 miles up the South Fork of Bubbs Creek, which is about 5 miles above the junction of Bubbs Creek with the South Fork of Kings River. The best way to reach the lake is by way of Millwood and Long Meadow, though it can be reached by a shorter route by packing from Independence, Inyo County, by way of Kearsarge Pass.

Starting with Long Meadow as a base (elevation 5,200 feet) the trail goes first to Bearskin Meadow, 5 miles distant and at an elevation of 6,000 feet; then to Horse Corral Meadow, 20 miles distant and at an elevation of 7,820 feet; then to Summit Meadow (overlooking Kings River Canyon), 23 miles distant and at an elevation of 8,150 feet; then to Kings River Canyon, 28 miles distant and at an elevation of 5,000 feet, a descent of more than 3,000 feet in 5 miles. About a mile upstream from the foot of this trail and approximately 12 miles above the junction with the Middle Fork of Kings River, is the log building known as the hotel and a sheep bridge across Kings River. The trail then leads up the South Fork of Kings River to Bubbs Creek, 37 miles distant and at an elevation of 5,370 feet, where the river makes a sharp bend to the north; then up Bubbs Creek to its south fork, 49 miles distant and at an elevation of 8,120 feet; up the South Fork of Bubbs Creek to East Lake, 52 miles from Long Meadow and 63 miles from Millwood, at an elevation of 9,350 feet. From where the trail enters Bubbs Creek it is very steep and rocky, and the 3 miles of it along the south fork of that creek would require a great deal of work to make it passable as a freight trail.

At East Lake the country in all directions is rugged and bare (see *Pl. XVII, B*), being near the limit of the timber line. Only a thin

A. LONG MEADOW DAM SITE.

B. EAST LAKE RESERVOIR SITE.

scattering of tamaracks is to be seen. At the time of the survey (July) considerable snow was still lying on the northern slopes and was feeding the South Fork of Bubbs Creek and its numerous lakes, which make this locality very picturesque.

About 2½ miles above East Lake is Reflection Lake (see Pl. XXI, *A*), which has a water surface of about 30 acres. It is a deep body of water between high, precipitous walls, and is at an elevation of 10,000 feet. Above Reflection Lake, at an elevation of 11,000 feet, are numerous small lakes of from 1 to 3 acres area, all perfectly calm, and reflecting the surroundings as in mirrors. Monuments were found at East Lake which showed that the California State engineering department had made a survey there. A topographic survey was made, under the direction of Mr. Green, with the following results:

East Lake is formed by an immense slide or moraine from Ouzel Creek Canyon on the west, which has dammed the South Fork of Bubbs Creek at that point. The creek formed a lake behind this moraine until it overflowed and washed out the channel where the dam would be located, but the bed of the channel is probably 50 or 60 feet above the old channel bottom, and the mass beneath and to the west is formed of huge blocks of granite embedded in granite débris. That it is not water-tight is proved by the fact that several small streams, caused by melting snow on the solid rock cliffs above the moraine, disappear at the contact of the moraine and appear as springs on the slope immediately above the lake.

There was a stream of water, estimated at 10 second-feet, flowing out of East Lake at the end of July, 1900. A weir dam which would raise the water 70 feet above the lake level would bring enough pressure to bear on the moraine to cause considerable leakage, but it would not wash out, there being too much rock in it, and there is the possibility that it might silt tight.

The area of the watershed tributary to East Lake is estimated at 2 square miles; the average elevation is 11,000 feet. The capacity of a reservoir raised 70 feet above the lake level, which was 9,350 feet at the time of the survey in July, would be 4,154 acre-feet. The lake itself could be utilized to some extent by deepening its mouth so as to permit of an outlet tunnel or pipe being placed low enough to draw off 30 or 40 feet of the water. This would add perhaps 400 acre-feet to the capacity of the reservoir. In like manner Reflection Lake could be utilized, and would yield probably 700 acre-feet additional, making a total of 5,250 acre-feet. No estimate has been made of the cost of a dam, because of the remoteness and inaccessibility of the locality, the cost of transporting material rendering such a project expensive to a degree out of all proportion to the limited capacity of the reservoir. There is no timber available with which to face the dam, and cement would cost from $15 to $20 a barrel delivered. A contour map of the East Lake reservoir site is shown in Pl. XIX.

While the camp was at East Lake a visit was made to Bull F Lake, on the north side of Bubbs Creek, about 4 miles east of the so fork of that creek and close to the summit of Kearsarge Pass. examination no dam site was found and the area of the lake ascertained to be so small as not to warrant any topographic wo The elevation of the lake is 10,600 feet; the elevation of Kearsa Pass, 3 miles east of the lake, is 12,000 feet. The drainage area the lake is about 5 square miles.

GRANITE BASIN.

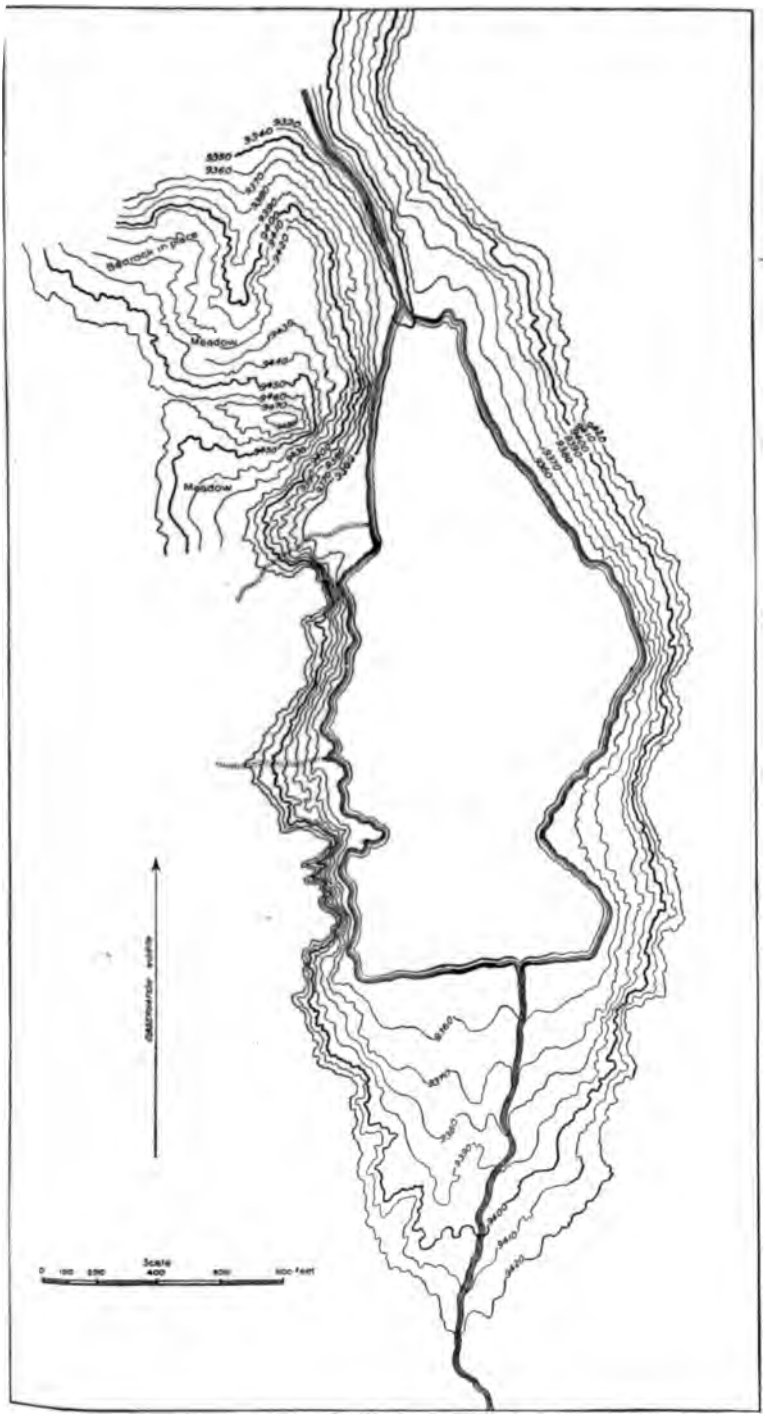
Granite Basin was the next place examined. It is on Granite Cre at the summit of the divide between Kings River Canyon on the So Fork and the Middle Fork of Kings River. It is reached by trail f Kings River Canyon. Starting at Kanawyer's cabin, elevation 5, feet, the trail ascends the steep spur on the west side of Cop Creek, follows Copper Creek for about 7 miles, and crosses the di at an elevation of 10,300 feet into Granite Creek on the west, 10 m from Kings River Canyon and at an elevation of 10,000 feet. A tour map of the reservoir site is shown in Pl. XX and a view of site in Pl. XXI, *B*.

There are two outlets, divided by a butte. The outlet to the no west would require a dam 750 feet long at the crest and 140 feet hi the outlet to the southeast of the butte would require a dam 900 long on the crest and 130 feet high to raise water to the plane of 10,000-foot contour. A view of one of the outlets is shown in XXII, *A*. The area within the 10,000-foot contour is 144 acres the capacity of the reservoir 10,350 acre-feet.

The drainage area tributary to Granite Basin does not exce square miles and averages 10,800 feet in elevation. There is a sp growth of tamarack scattered over the basin, the whole of wh however, is practically bare and barren. The bed rock is gran The capacity of the reservoir compared with the cost of the two la dams necessary to create it and the difficulty of access render project impracticable.

ELECTRIC-POWER DEVELOPMENT.

In a study of the various irrigation possibilities of Kings Riv was deemed advisable to investigate the water power obtainable the purpose of generating electric energy for transmission to l pumping plants in the valley. This requires an investigation of t distinct phases of the problem: (1) The available power; (2) available ground-water supply for pumping at or near the irrig lands; and (3) the generation and transmission of electric power the installation of pumping plants. The subject will be treate that order. Mr. H. E. Green was detailed to investigate the w power, Mr. Louis Mesmer the water supply for pumping, and Lewis *A. Hicks* the power transmission and pumping plants.



CONTOUR MAP OF EAST LAKE RESERVOIR SITE.

CONTOUR MAP OF GRANITE BASIN RESERVOIR SITE.

POWER POSSIBILITIES.

From Granite Basin the trail passes over a nude and rugged granite country until it drops suddenly into the beautiful Middle Fork Canyon (see Pl. XXII, *B*), at Simpson Meadows, 10 miles from Granite Basin and at an elevation of 6,000 feet. Tehipiti Valley is about 15 miles down the canyon from Simpson Meadows, but the canyon is practically impassable, so the party went by way of Collins Meadow.

Leaving the Middle Fork, elevation 6,000 feet, the trail ascends the West Branch of Goddard Creek and in a distance of 4 miles climbs nearly 5,000 feet up a hard, rocky mountain, with only one bench on which to rest animals and adjust packs. From the top of the ridge, elevation 10,600 feet, a magnificent view is obtained of the country to the south and east across the South Fork of Kings River and Bubbs Creek to the watershed between Kings and Kern rivers. The trail then follows easy country to Collins Meadow, 30 miles from Simpson Meadows, elevation 7,600 feet. Coming from Fresno by way of Ockenden this point is the natural entrance to Tehipiti Valley. From Ockenden there is a wagon road for 15 miles, to Russel's camp, southeast of that place. From Russel's camp the trail follows undulating and pine-covered country presenting easy grades for a continuation of the wagon road toward the North Fork of Kings River. The trail reaches the North Fork at Cliff camp, about 15 miles from Russel's camp and about 3 miles below the Dusy Meadows dam site. The trail to Dusy Meadows branches off about 3 miles before reaching the North Fork.

There is a good bridge site at the North Fork crossing, where the stream is confined between perpendicular walls of granite about 70 feet apart. (See Pl. X.) From the North Fork crossing the trail continues over rolling ground covered with pine and traverses many open glades which have good feed in the spring of the year. Collins Meadow is reached at a distance of 10 miles from the North Fork. From that meadow the trail to Tehipiti Valley turns south and follows easily along a sloping bench between the saw-tooth Tombstone Ridge on the west and Crown Creek, to the head of the steep descent (2,500 feet in 3 miles) to Tehipiti Basin. The elevation at the top of this steep trail is 6,500 feet and at the bottom 3,950 feet. At the junction of Crown Creek with the Middle Fork, in Tehipiti Valley, and dividing the two creeks, rises sheer from the bottom of the basin, 3,350 feet in elevation, the remarkable Tehipiti Dome.

A survey of the basin was made with enough detail to give roughly the capacity of a reservoir with a dam 150 feet high. The area of the reservoir would be 218 acres and the capacity 10,000 acre-feet. The dam would be 1,000 feet long on its crest. On the west side the material is all loose, being a talus from a high cliff. On the east side some bed rock is visible where a spring torrent has washed out a

channel, but there is no really good dam site. On August 26 the river was measured at a favorable place in the valley and 153 second-feet were recorded.

Having connected the survey with Tehipiti Dome a traverse line was run down the Middle Fork Canyon toward the South Fork junction, to ascertain the fall that would be available for power development. (See profile of river, Pl. XXIII.) The canyon is a difficult one to traverse, and without a very expensive trail the traverse would have been impossible had the water in the river not been low enough to permit the continual crossing and recrossing of the stream. Five miles of the canyon were traversed from the camp at Tehipiti, and this being the limit of walking distance for a day's work, and the junction not being in sight, the camp was moved, by way of the North Fork and the main river, to the junction. A typical view of the canyon of Kings River near the junction of the South and Middle forks is shown in Pl. XXIV, *B*. Pl. XXIV, *A*, is a view looking up the Middle Fork, and shows in the foreground its junction with the South Fork.

Leaving Tehipiti the trail by way of Collins Meadow (elevation 7,600 feet) and Garlic Meadows (elevation 8,000 feet) was taken to the mouth of the North Fork of Kings River (elevation 800 feet), a distance from Tehipiti of 35 miles. By this time the pack animals were in very poor condition from scarcity of feed, owing to the repeated dry seasons, and forage had to be carried up Kings River during all subsequent work. On September 13 the party started a traverse up Kings River from the mouth of Mill Flat Creek, where the Sanger Lumber Company's flume enters the canyon (elevation 880 feet), to the junction of the Middle and South forks, a distance of 14 miles by traverse line and estimated to be 30 miles by trail. The elevation at the junction was found to be 1,950 feet. The junction of the Middle and South forks was reached October 8, after an arduous trip, for a great deal of brush-cutting and considerable pick and shovel work had to be done to get the animals safely over bad places.

The Middle Fork work was continued from 5 miles below Tehipiti and was joined to the main river survey. A traverse line was then started with a view to ascertaining the distance and grade of the South Fork Canyon up to the "hotel." This survey, however, was prevented by an impassable canyon 2½ miles above the junction, and it being near the end of October further exploration work was postponed. On October 20 the river was measured below the junction of the Middle and South forks and a flow of 346 second-feet was recorded. The traverse of the main river developed the fact that from the junction of the Middle and South forks the grade for 14 miles down the river, or to the mouth of Mill Flat Creek, averages 76.4 feet to the mile. For 3 miles below the junction the grade is only 72 feet to the mile. It then increases to a maximum of 103 feet per mile, gradually

A. REFLECTION LAKE.

B. GRANITE BASIN RESERVOIR SITE.

A. OUTLET OF GRANITE BASIN RESERVOIR SITE.

B. CANYON OF MIDDLE FORK ABOVE TEHIPITI BASIN.

lessening, until above Mill Flat Creek for 3 miles it averages 54 feet per mile.

The survey of the South Fork was not finished, but the work that was done warrants the belief that as good a power plant can be developed there as on the Middle Fork. For this reason the site for the power house was chosen on the peninsula between the Middle and South forks (see Pl. XXV), so that either or both could be used. A conduit from the South Fork brought down the North Fork side of the canyon could be taken to the same penstock, if necessary, as the Middle Fork conduit. In any event the site proposed for the power house is in the most advantageous position to utilize water power from both forks. A preliminary estimate was made of the cost of a conduit to carry sufficient water out of the Middle Fork to generate 6,500 horsepower at the junction of the Middle and South forks. The estimate embraces the necessary works from the intake to the penstock. The location on the Middle Fork was selected because of the heavy fall of the stream at that point. The works would be in the canyon of the Middle Fork and would be reached by way of Millwood and the Sanger Lumber Company's road, already described, which runs to within 6 miles of the junction of the Middle and South forks. The descent in those 6 miles is about 3,000 feet, and will require a 10-per cent graded road. To reach the site of the proposed power house a bridge will be necessary across the South Fork and 6 miles of trails will be needed up the canyon of the Middle Fork and around the works. The intake or headworks would be between 3 miles and 3½ miles up the Middle Fork, whence the water will be conveyed in a series of short tunnels with a maximum single length of 1,500 feet. The tunnels will be in granite, unlined, and 6 feet by 6 feet in the clear. Adits in canyons will be arched over, allowing storm water a clear way. This form of construction is not only of a permanent nature, but it requires the minimum hauling of material and supplies into the canyon.

Following is the estimate of cost:

Cost of conduit out of Middle Fork.

Road into canyon, 6 miles at $8,500	
Bridge across South Fork	
Trails in canyon of Middle Fork, 6 miles at $500	
Tunnels (Burleigh drill work), 14,000 feet at $12	
Headworks, including masonry diverting dam, shaft for inlet, t entrance gate, screen, etc	
Adits to tunnels, 14 at $500	
Engineering and contingencies, 15 per cent	
Total	

The elevation of the intake would be 2,700 feet, the el the penstock 2,660 feet, and the elevation of the power h feet. The available head is 650 feet. The estimated mean horsepower equals

$$\frac{\overset{\text{h.}}{650}\times\overset{\text{s.-f.}}{100}\times\overset{\text{lbs.}}{62.5}}{550}, \text{ or } \frac{650\times100}{8.8}, = 7{,}386.$$

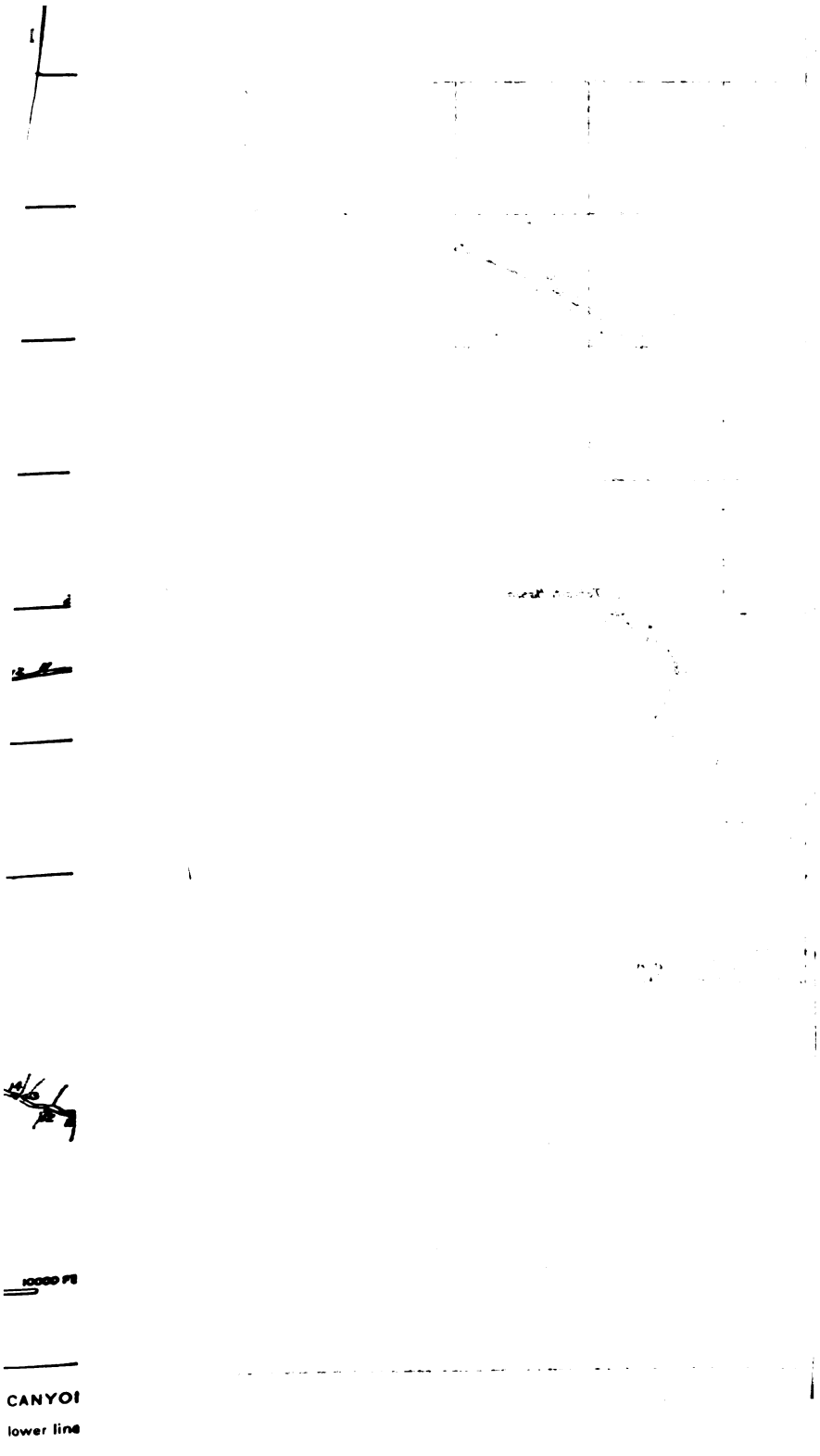
With 150 second-feet passing through the tunnel the h equals

$$\frac{650\times150}{8.8}=11{,}000.$$

With 180 second-feet passing through the tunnel the h equals

$$\frac{650\times180}{8.8}=13{,}300.$$

During the late summer, when Kings River is at its minir practically all of its water is coming from the higher drained by the Middle and South forks. In dry years Fork delivers in September about 10 second-feet, which enough to make good the loss by evaporation in the main the junction to the Red Mountain gaging station. It is be there is as much water at the junction as at Red Mountain. tions on the main river at Red Mountain covering the mont August, and September of the years 1896 to 1900, inclusiv that had the proposed tunnel conduit been in operation d time it could have been filled to its maximum capacity of feet during the whole of the month of July of each year. whole of August of the same years the tunnel could have be with 100 second-feet of water, and for 75 per cent of the ti have had 150 second-feet. During September of the sa supply of 100 second-feet could have been obtained three-f


10000 FT
CANYO
lower line

DDLE FORK OF KINGS RIVER ABOVE JUNCTION OF SOUTH FORK.

B KINGS RIVER CANYON.

time and an average of 85 second-feet during the remaining two-fifths of the time—the exceptionally dry years of 1898 and 1899. With 650 feet head the 85 second-feet would yield

$$\frac{\overset{h.}{650} \times \overset{s.-f.}{85}}{8.8} = 6{,}250 \text{ horsepower.}$$

This means that during every month of each of the foregoing years, excepting the two months of August and September, the conduit could have carried its maximum capacity of 180 second-feet.

Careful measurements should be made of the Middle and South forks to determine their respective volumes of flow before construction is attempted.

GROUND WATER OF KINGS RIVER DELTA.

The territory with a deficient water supply is that covered in the main by the Fowler Switch, the Alta District, the Kingsbury, and the Last Chance canals, Peoples' ditch, and the Fresno canal. A late summer supply would permit the production of alfalfa and other products. The natural drainage of these lands is toward the southwest, at the rate of about 6 feet to the mile. The soil is largely granitic sand, and below an average depth of 10 or 15 feet it is saturated with water. The surface water is somewhat alkaline, and therefore it is not advisable to pump it for irrigation. Water below a depth of 50 feet can be considered satisfactory for irrigation. This is based on tests of more than 800 wells in the district, some of them being in sections where there were the strongest surface alkaline indications. In every case this lower water was found to be good, and when the strata near the surface are penetrated it rises to the elevation stated.

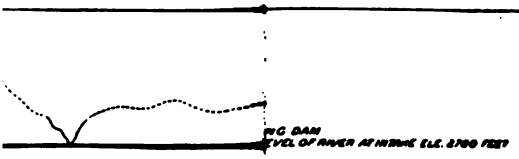
There have been few attempts to pump water in larger quantity than is required for domestic purposes. A 2-inch screw pipe put down to an average depth of 50 feet, landing the pipe on a stratum of clay and then boring through the clay and allowing the water to come in from the bottom of the hole, is always ample for this purpose. Locally it is the common impression that by boring through two or three strata of clay or hardpan all of the surface water is shut off, thus exempting the consumers from one of the supposed causes of malaria. An abundant supply of water at 20 or 30 feet could be obtained, but the quality would not be so good.

One of the largest pumping plants in this vicinity is that of the Fresno Domestic Water Company, the water supply for which is obtained from unperforated wells at a depth of 600 feet. In this case an ample supply (about 4 second-feet) for a city of 12,000 inhabitants is obtained from a city lot 50 feet by 150 feet. In and around Fresno a number of wells have been put down for street sprinkling. These

wells are 8 inches in diameter and do not exceed 70 feet They are unperforated, excepting perhaps the lower join the pipe, and practically all of the water comes from t With a 2½-horsepower engine they fill a 1,250-gallon tank 9 the surface in five minutes, or at the rate of more than foot, lowering the water plane during the pumping not to 6 feet below its normal elevation. A few small pumping p been installed—one 5 miles east of Fresno, on Minnew several around Selma, and two near Wild Flower—which yi 0.5 second-foot to a 7-inch unperforated well not more t deep, with a lift not to exceed 20 feet in any case.

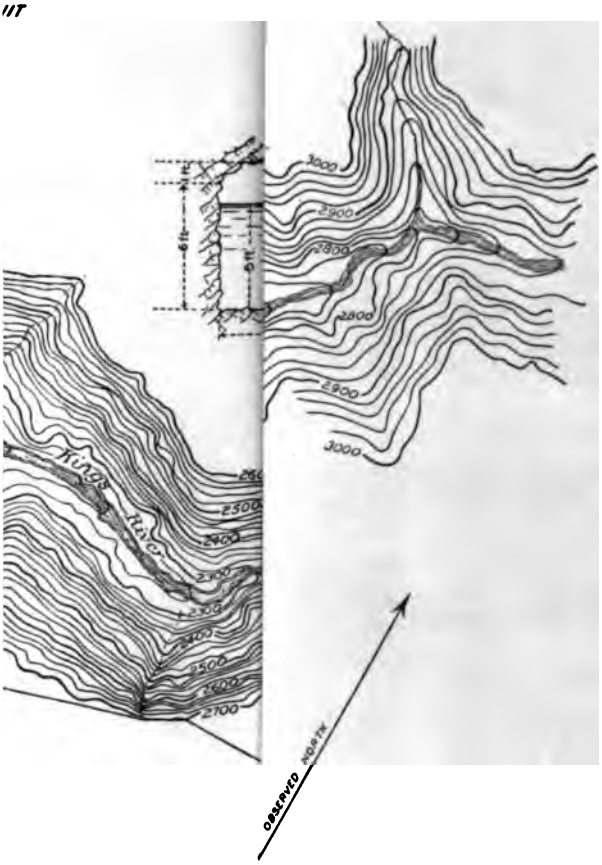
Wells of about 10-inch or 12-inch casing should be put depth of about 100 feet on an average, and should not be above 50 feet below the surface, thus shutting off all possi of drawing from the more or less alkaline surface water. able that wells of this size and depth would each furnish feet. A well driller in Selma states that he will put 12 down to a depth of 150 feet and guarantee them to furnish feet each, without perforations, at a cost not to exce well.

Pl. V is a map of Kings River delta showing the distribu and the location of the wells visited during the investiga numbers of the wells on that map correspond with the num following table, which gives the details concerning each principal facts regarding the wells are given in abbrevi In the first column is the number of the well, as shown o Pl. V. In the next column is the name of the owner, and that the location, by township, range, and section; the pleted; and the class of well, the latter being indicated by meaning dug well, *Dr* driven well, and *B* bored well, the a ing figures giving the average diameter or width, in inches- ple, *D36* means a dug well 36 inches across. The depth of t depth to water, and the depth of the water in the well, all given in the next columns. These columns are followed by the character of the strata, which is indicated by initials, clay, *G* gravel, *Gr* decomposed granite, *L* loam, *S* sand, *Q* q *Qs* quick-sand, and *Hp* hardpan. To illustrate: *LSG* is eq loam, sand, and gravel. The next column (right-hand pag quality of the water, whether hard, soft, alkaline (*alk*), c ous (*sul*). The next one gives the method by which t obtained, the word *hand* meaning hand pump, *horse* a h machine, and *wind* a windmill. In the latter case the a ing figures give the diameter of the windmill, in feet. Fo *14 wind* is intended to imply that water is pumped by a 14 mill. The cost of the well and of the machinery is given



6650 feet

IIT



G LOCATION OF POWER HI

wo columns. Following that is the character of the supply, *good* ndicating a good supply and *small* a small or deficient supply; vhere the quantity is given it is in gallons per day of twenty-four iours. In the next column, headed "Use of water," the abbreviation *lom* implies domestic use, *st* implies use for watering cattle and iorses, and *irr* that water is also used for irrigation. The last col-umn gives the relative salinity of the water in parts per 100,000. As a rule the water in most of the wells varies in quantity as a result of irrigation, the fluctuation being within limits of a few feet.

Wells in Kings River delta—

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well. Feet.	Depth to water. Feet.	Depth of water. Feet.	Strata.
1	R. A. James	14	23	10	1893	D36	14	12	2	GB
2	L. W. Hobler	14	23	14	1894	Dr2½	14	10	4	GB
3	Mount Camel Vineyard.	14	23	23	.....	D36	.....	12	.....	Gr
4	76 Company	.....	.....	.....	.....	B4	.....	33	.....	.....
5	W. S. Goodfellow	.....	.....	.....	1894	Dr1½	.....	10	.....	LSGB
6	E. J. Bullard	13	19	2	.....	B2	.....	65	.....	.....
7	P. M. Hart	13	20	8	.....	B7	.....	.....	.....	.....
8	.....	13	20	10	.....	B5	.....	.....	.....	.....
9	H. Johnson	13	20	3	.....	B	.....	.....	.....	.....
10	J. H. Funck	13	20	3	1892	B7	80	32	48	.....
11	H. V. Parker	13	20	10	1891	B8	105	30	75	.....
12	.....	13	20	11	.....	B5	.....	28	.....	.....
13	Gus Ploetz	13	21	6	1895	B5	80	28	52	.....
14	W. M. Shortridge	13	21	5	1897	B5	36	8	28	GCQs
15	R. T. Oven	13	21	8	1881	B7	90	13	77	LHpCG
16	T. L. Hunter	14	20	4	1898	B7	55	5	50	LG
17	Mr. Roeding	13	20	32	.....	B3	60	.....	.....	.....
18	M. Dunlavey	13	20	33	1895	B5	90	7	83	LG
19	William Shepp	13	20	33	1898	B2	56	9	47	LGCS
20	....do	13	20	29	.....	B2	.....	10	.....	.....
21	J. Mills	13	20	29	1892	B5	80	8	72	LG
22	M. Jensen	13	20	29	1888	B2	85	12	73	.....
23	J. P. Green	13	20	19	1898	B2	104	14	90	.....
24	August Bopp	13	20	19	1892	B3	65	15	50	Hp
25	Conrad Bopp	13	20	19	1898	D36	17	16	1	Hp
26	Mrs. E. G. McCardle	13	19	24	1900	B6	96	27	69	SG
27	W. N. Harris	13	20	19	1894	B2	.....	22	.....	.....
28	E. G. Dickinson	13	20	19	1894	B2	44	20	24	G
29	F. G. Foster	13	20	19	1898	B5	104	28	.....	.....
30	S. E. Ward	13	20	19	1892	B6	95	25	70	HpS
31	A. S. Coon	13	20	20	1880	B6	125	18	107	.....
32	.....	13	20	20	.....	B2	.....	16	.....	.....
33	B. T. Tipton	13	20	20	.....	B6	70	16	54	.....
34	Wm. N. Fuller	13	20	29	1897	B2	76	6	70	HpSG
35	G. M. Boles	14	20	4	1897	B6	65	6	59	.....
36	Abraham Wade	13	20	33	1898	B3	70	6	64	.....
37	Jno. Barry	13	20	34	1895	B2	50	6	44	.....
38	C. D. Edgerly	13	20	27	1890	B2½	85	10	75	.....
39	Mr. Bailey	13	20	28	1896	B2	55	9	46	.....
40	.....	13	20	21	.....	B6	.....	17	.....	.....
41	T. C. White	13	20	22	.....	B7	50	18	32	.....
42	.....	13	20	10	.....	B7	40	21	19	.....
43	J. Wallers	13	20	10	1890	B6	65	24	41	.....
44	C. W. Stevens	13	20	14	1892	B7	.....	17	.....	.....
45	Wm. Bitner	13	20	14	.....	B2½	.....	15	.....	.....
46	H. J. Lorgenson	13	20	14	1892	B2	35	.....	.....	.....
47	M. J. Miles	13	20	11	.....	B3	.....	.....	.....	.....
48	Mr. Helm	13	20	12	.....	B7	.....	.....	.....	.....
49	G. G. Besigger	13	21	19	1891	B6	82	9	73	.....
50	Jno. Swenson	13	21	19	.....	B	80	8	72	.....
51	Mr. Wolf	13	21	19	.....	B	.....	.....	.....	.....
52	Eggars estate	13	21	30	1897	B	.....	.....	.....	.....
53	Ger. S. and L. Bank	13	21	19	.....	B6	.....	9	.....	.....
54	C. G. Anderson	13	21	30	1880	B6	53	8	47	G
55	Esmeralda Vineyard Co.	13	20	35	1891	B2	65	7	58	.....
56	.....	13	20	34	.....	D3x5	9	7	2	.....
57	Geo. I. Helm	13	20	26	.....	B	.....	7	.....	.....
58	W. J. Dickey	13	20	25	1892	B7	120	7	113	.....
59	J. P. Thomas	13	20	25	1884	B2	76	6	70	.....
60	.....	13	21	30	.....	B	.....	7	.....	.....
61	E. J. Azbderian	13	21	31	.....	Dr	.....	.....	.....	.....
62	F. M. Roessler	13	21	30	1890	B2	50	6	44	SLGHpQs
63	G. R. Shipp	13	21	30	1892	B3	83	8	75	.....
64	Guthrie Co	13	21	31	1890	B	80	6	74	.....
65	E. Kennedy	13	21	31	1887	B6	72	8	64	.....
66	Mr. Forsyth	13	21	32	.....	B	.....	.....	.....	.....
67	Guthrie & Co	13	21	32	.....	B4	.....	7	.....	.....
68	G. R. Taylor	13	21	33	.....	B	90	.....	.....	.....
69	Y. Locan	13	21	32	.....	B2	100	7	93	.....
70	L. L. Desnhar	13	21	32	1884	B	85	6	79	.....
71	Eggars estate	.....	.....	.....	.....	B8	.....	6	.....	.....
72	Olsen estate	13	21	19	1899	B6	80	7	73	SLHpCG

* Where the quantity is given it is in gallons per day of 24 hours.

Tulare, and Kings counties.

of	Method of lift.	Cost of well.	Cost of machinery.	Supply.[a]	Use of water.	Salts, parts per 100,000.
..	Hand			Good	Dom	14
..	do	$10.00		do	do	8
..	do				do	10
..	Horse				Stock	
..	Hand		$4.00		Dom	8
..	Wind				Dom; st	12
..	do			3,000 gallons	do	11
..	Hand			Good	Dom	8
..	Wind			do	Dom; st	11
..	Hand			do	Dom	11
..	14 wind			2,000 gallons	Dom; st	11
..	Hand				Dom	10
..	Wind				do	9
..	12 wind	18.00	45.00		do	15
..	Wind			Good	do	11
..	Hand			do	do	11
..	12 wind			do	Dom; st	12
..	Hand		105.00	do	Dom	12
..	do	15.00	1.50	do	Dom; st	10
..	do			do	Dom	8
..	do	40.00	25.00	do	do	8
..	Wind	34.00	75.00	do	do	10
..	Hand		55.00	do	do	9
..	do	30.00	5.00	do	Dom; st	9
..	Rope			Small	Dom	9
..	Hand				do	8
..	do		4.00	Good	Dom; st	8
..	do				Dom	8
..	do	75.00		Good	do	8
..	do	45.00	15.00	do	do	8
..	do		6.75	do	do	10
..	do				do	
..	do		3.00	Good	do	8
..	8 wind	20.00	41.00	do	do	8
..	Wind			do	Dom; irr	12
..	8 wind			do	do	11
..	Hand		25.00	do	Dom	10
..	18 wind		35.00	do	do	11
..	Hand			do	do	
..	Wind				do	8
..	do			Good	do	8
..	Hand			do	do	12
..	do		80.00	do	do	11
..	8 wind			do	do	10
..	Hand		5.00	do	do	10
..	do			do	do	10
..	do			do	do	12
..	14 wind			do	Dom; st	10
..	Hand			do	Dom	12
..	do		5.00	do	do	8
..	do			do	do	8
..	Wind			do	do	12
..	Hand			do	do	8
..	Wind			do	do	8
..	Hand		5.00	do	do	8
..	Lever	6.00	1.50	Small	Dom; irr	15
..	Wind			Good	Dom	14
..	Gas; hand			do	do	12
..	do		5.00	do	do	10
..	Hand			do	do	8
..	do		5.00	do	do	9
..	Wind			do	do	12
..	do	83.00	170.00	do	do	12
..	do			do	do	13
..	do			do	do	
..	do			do	do	11
..	do			do	do	9
..	do			do	Dom; st	10
..	do			do	Dom	6
..	do	85.00	130.00	do	do	9
..	Steam			30,000 gallons	Winery; dom	13
..	Steam; wind	100.00		Good	do	12

Wells in Kings River delta—

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well. Feet.	Depth to water. Feet.	Depth of water. Feet.	Stra
73	Paul Leonhart	13	21	19	1889	B1½	70	9	61	
74		13	21	19		B7		10		
75	S. P. Co	12	19	5	1887	D12 / B8	140	85	55	LHpGCS
76	Thornton estate	12	19	34		B8				
77	Lee Cobb	12	19	35		B7				
78	E. J. Bullard	12	20	31	1886	B8		70		HpSGC
79	do	13	20	5		B8		100		
80	J. H. Randel	12	20	34		B6	70	60	10	
81	E. J. Lane	12	20	22	1894	B8	99	85	14	CSG
82	Frank Lane	12	20	15	1886	B		85		
83	J. P. Williams	12	20	14		B6	115	90	25	
84	Sacramento Bank	12	20	13		B6		80		
85	A. B. Ball	12	21	7	1892	B6	145	80	65	G
86	Gudlip Ambrosia	12	20	24	1891	B6		68		
87	Harry Maupin	12	20	25	1885	B6	113	48	65	CGS
88	Geo. Johnson	12	21	19		B5		38		
89	F. E. Brown	12	21	20	1890	B7		34		
90	W. Foster	12	21	19	1892	B7	75			
91	B. F. Parker	12	21	17	1881	B7	93	35	58	CG
92	J. W. Brown	12	21	18	1882	B7	100	45	55	CSG
93	Milo Rowell	12	21	5	1880	B7	130	60	70	
94	J. M. Heiskell	12	21	8	1880	B7	100	63	70	C
95	Chas. Brown	12	21	4	1900	D48		50+		CG
96	Mrs. Birkhead	12	21	4		D48	26	18	8	(a)
97	V. B. Cobb	12	21	9		D54	47+	33	14+	(b)
98	J. M. Heiskell	12	21	10		D–B		22		
99	Fresno National Bank	12	21	15	1889	B8	86	18	68	CG
100	J. H. Barker	13	20	15	1891	B2	60	15	45	
101	F. M. Merrit	13	20	14		B7	100+	14	86	
102	Mr. Moon	13	20	23		B2	45	13	32	
103	Bismarck Vineyard	13	21	29		B2		6		
104	P. H. McGarry	13	21	21	1891	B5	80	6	74	
105	M. F. Tarpey	13	21	21		B2	110	7	103	
106	Mr. Hein	13	21	28		B2		6		
107	Andrew Palm	13	21	15	1891	B2	85	6	79	L
108	G. J. Tyler	13	21	16	1900	B2	81	14	67	L
109	H. J. Clifford	13	21	9	1894	B1½	80	14	66	
110	C. R. Damon	13	21	8	1898	B5	54	10	44	LHpCG
111	J. W. Sharer	13	21	15	1890	B6	80	9	71	L
112	J. Darnold	13	21	9		B7		8		
113	G. W. Green	13	21	4		B5		9		
114	A. Henderson	12	21	33	1888	B5	77	10	67	
115		12	21	33		B		11		
116		13	21	5	1896	B5	50	15	35	
117		12	21	34		B5		14		
118	Sheppard & Teague	12	21	28		B8		12		
119	Chas. A. Owens	12	21	30	1879	D	90	26	64	
120	H. B. Bissell	12	21	28		B8		12		
121	W. E. Parker	13	21	5	1895	B5	50	12	38	LHpAshS
122	Cates estate	13	21	2	1894	B7	40	10	30	
123	J. W. Potter	12	21	34	1892	B6	50	12	38	
124	do	12	21	26	1877	B8	60	20	40	G
125	do	12	21	26	1899	B8	50	12	38	
126	do	12	21	35	1873	D60	45	18	27	
127	Miss. schoolhouse	12	21	22		B6		9		
128	T. C. White	12	21	22	1895	D60	14	9	5	
129	T. P. Nelson	12	21	14	1888	B6	25	13	12	LHpC
130	Bank	12	21	11		D60	40	20	20	C
131	Reese estate	12	21	13		B9		13		
132	J. E. Dickerson	12	21	23	1880	B8	50	11	39	
133	J. D. Collins	12	21	24	1880	B6	54	14	40	
134	Clovis Cole	12	22	31		D48	31	25	6	
135	Bank	12	22	31		B6		16		
136	D. C. Sample	12	22	32		D60	40	30	10	
137	do	12	22	29		D48	25	24	1	CHp
138	do	12	22	21		D48	14	12	2	
139	Marvin Simpson	12	22	27	1899	D60	25	24	1	Soil
140	Alfred Beard	12	22	26	1890	D60	18	14	4	Gr
141	do	12	22	27	1893	D60	13½	6	7½	QsHpCG
142	Jack Simpson	12	22	22	1898	D60	25	20	5	GCSGr
143	B. Simpson	12	22	14	1890	D60	22	15	7	CGr
144		12	22	34		D60	17	14	3	

[a] Heavy soil and adobe rock.

Kings counties—Continued.

Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Hand	$30.00	$5.00	Good	Dom	8
Wind			do	do	8
Steam			3,125 gallons	Dom; boilers of S. P. Co.	9
4 wind			Good	Dom; st	9
2 wind			do	do	10
4 wind			do	do	8
wind			do	do	11
Horse			do	do	13
wind	145.00	41.00	do	do	12
6 wind			do	do	12
do			do	do	11
Hand			do	do	
6 wind			do	do	11
do			do	do	12
4 wind	113.00	90.00	do	do	11
Hand			do	Dom	11
Wind			do	Dom; st	9
do			do	Dom	10
6 wind	100.00	125.00	do	Dom; st	12
Wind			do	do	11
4 wind		174.00	do	Dom	10
do			do	Dom; st	13
6 wind				do	14
Hand		5.00	Small	do	13
Rope				do	24
4 wind			Good	do	12
1 wind		30.00	do	do	15
Hand		5.00	do	Dom	11
Wind			do	Dom; st	13
Hand		5.00	do	Dom	8
2 wind			do	do	13
Hand	40.00	50.00	do	do	13
wind	33.00		do	Dom; st	13
Hand		6.00	do	do	15
do	25.00	5.00	do	do	10
wind	25.00	100.00	do	Dom	8
Hand	60.00	5.00	do	Dom; st	13
do	175.00	18.00	do	do	12
do			do	do	8
do			do	Dom	13
Wind			do	Dom; st	10
wind			do	do	16
Hand		5.00	do	Dom	13
do		5.00	do	Dom; irr	11
do	22.00	5.00	do	Dom; st	13
wind			do	Dom	11
2 wind			do	Dom; st	9
wind			do	do	11
Hand	37.50	48.00	Small	do	13
Wind		5.00	Good	do	13
Hand			do	do	11
wind		35.00	do	do	15
Hand		5.00	do	do	13
wind			do	do	21
Hand		5.00	do	Dom	
Rope			Small	Dom; st	
Hand		5.00	do	do	13
do		5.00	do	do	13
Horse			Good	Stock	20
4 wind			do	Dom; st	16
Hand			Small	do	21
6 wind			do	do	
Hand			Good	do	21
3 wind		55.00	do	do	13
6 wind		25.00	Small	do	28
3 wind			Good	Stock	25
Hand			Small	Dom; st	
3 wind	50.00	45.00	Good	do	12
Hand	9.00	5.00	do	Dom	13
3 wind	10.00	36.00	Small	Dom; st	18
Wind			Good	do	14
Horse			Small	Stock	

[b] Heavy soil.

Wells in Kings River delta–

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Str
							Feet.	*Feet.*	*Feet.*	
145	Bank of Sacramento	13	22	2		D36	14	10	4	
146	W. M. Harbison	13	22	10	1882	B6	82	37	45	CHpG
147	T. C. White	13	22	9	1882	B8	75	35	40	
148	C. J. Reyburn	13	22	9	1882	B8		33		
149	Redbanks schoolhouse	13	22	8		B7		26		
150	A. Gordon	13	22	8		D60	20	14	6	
151	B. F. Griffen	13	22	6	1880	D60	50	28	22	
152	A. H. Hamilton	13	22	7	1875	D60	60	25	35	CHpG
153	Fresno L. and S. Bank	13	22	6	1882	D60	37	18	19	G
154	do	13	22	6	1880	B7		32		G
155	R. G. Hewitt	13	21	14	1892	B2	90	12	78	
156	Sam Ebe	13	22	8		D48		11½		
157	S. F. Bank	13	22	8	1882	D60		21		
158	Sacramento Bank	13	22	8	1880	D48	60	22	38	
159	Jno. Lee estate	13	22	16	1880	B6	60	23	37	
160	J. M. Ellmore	13	22	15	1884	B8	80	37	43	G
161	Alfred Beard	13	22	15	1885	B8	75	38	37	
162	Mr. Gibson	13	22	14	1880	D54		30		
163	Mr. Meyers	14	20	2	1890	B2	30	15	15	
164	County of Fresno	14	20	2	1897	B7		10		
165	J. Nishkian	14	21	6		B2		8		
166	L. Dalton	14	21	6	1892	B2	80	15	65	L
167	J. Steinivaud	14	21	6	1882	B6	45	6	39	LHpCG
168	St. George Winery	14	21	5	1894	B10	300	6	294	
169	W. E. Carrico	13	21	33	1885	B5	78	9	69	LHpGC
170	H. J. Eaton	13	21	33		B2		9		
171	S. E. Mill	13	21	34	1899	B2	70	12	58	G
172	Miss Ethel Shell	13	21	34	1898	B2	79	12	67	LCSG
173	Geo. C. Roeding	14	21	3	1885	B8	90	8	82	G
174	Judge Wallace	13	21	35	1899	B2	45	20	25	S
175	G. B. Passon	13	21	36	1893	B2	40	14	26	
176	M. E. Laymensce	13	21	36	1891	B2	60	8	52	CHp
177	E. L. Curtis	13	22	31		B		7		
178	Mr. Wright	14	22	6	1898	B2	65	10	55	SG
179	R. B. Baird	13	22	32	1900	B2	75	11	64	S
180	Sacramento Bank	14	22	5		B5		9		
181	S. F. Savings Union	13	22	32		B6	85	16	69	
182	W. O. Blasingame	14	22	4		B72	60	10	50	
183	Dr. Chester Rowl	14	22	4	1897	B2	95	14	71	LHpCS
184	Fresno Milling Co.	14	20	3	1897	B2	81	12	69	SLGC
185	Jno. D. Rutledge	14	20	4	1897	B2	75	6	69	SG
186	C. W. Forsman	13	20	34	1888	B2	60			S
187	A. Vogel	13	20	34	1888	B4	60	8	52	SC
188	Mr. Hayes	13	20	35	1882	B7	70	11	59	
189	Joseph Bocarde	14	20	2	1895	B3	75	20	55	LHpQsS
190	Mr. Dickerson	13	20	35	1884	B1½		8		
191	J. W. Martin	13	20	35	1888	D2	12	7	5	L
192	G. T. Hawley & Bro	13	20	35	1895	B2	90	15	75	G
193	San Ricardo Vineyard	13	21	31		B		10		
194	H. M. Rustigian	14	21	6	1891	B2	60	12	48	
195	J. Rustigian	14	21	6		B2		10		
196	C. D. Wright	14	21	5	1896	B2	80	8	72	
197	Geo. Goodrich	13	21	33		B2	75	7	68	
198	Frank Green	13	21	33	1892	B2	60	9	51	G
199	N. C. Skoegard	13	21	33	1885	B2		8		
200	Alice Treadwell	13	21	34	1887	B2	85	10	75	SG
201		13	21	27	1899	B2		9		
202	L. M. Fincher	13	21	22	1880	B8	75	6	69	CS
203		13	21	15		B2		7		
204	N. A. Shelling	13	21	15		B2		8		
205	E. E. Irwin	13	21	14	1885	B8	85	9	76	CGS
206	W. Davenhill	13	21	14	1894	B2		7		
207	J. D. Reyburn	13	21	11	1892	B7	85	12	73	LHpS
208	Geo. P. Byreborg	13	21	14	1890	B2	90	16	74	GCHpQs
209	A. J. Cass	13	21	14	1891	B2	60	9	51	
210	Mr. Herman	13	21	24	1897	B2	40	8	32	CHpCSG
211	McDonald estate	13	22	18	1877	D48	80	15	65	
212		13	22	18		D48		11		
213		13	22	19		B2	17	14	3	
214	Samuel Funck	14	20	3	1890	B1	75	12	63	LHpCSG
215	R. J. Robinson	14	20	3	1900	B2	73	10	63	S
216		14	20	2		B2		10		
217	Thos. Hughes, vin	14	20	11		B		8		
218	D. J. Vaughn	14	20	12	1882	B5	65	9	56	LCSG

d Kings counties—Continued.

Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Hand		$5.00	Small	Dom; st	15
10 wind		90.00	Good	do	15
Hand		6.00	do	do	12
Wind			do	do	12
Hand			do	Dom	14
Rope				Dom; st	
8 wind		40.00	Good	Dom	11
Wind	$50.00	130.00	do	Dom; st	15
do		14.00	do	do	17
14 wind			do	do	17
Hand		5.00	do	do	12
do			do	do	14
Wind			do	do	14
do			do	Dom	13
8 wind		40.00	do	Dom; st	12
10 wind	80.00	165.00	do	do	15
Wind		35.00	do	do	13
Rope			do	do	15
Hand	15.00	4.25	do	do	12
Gas			288,000 gallons	Streets	20
Hand		4.25	Good	Dom; st	11
8 wind	30.00	79.00	do	do	8
Hand	40.00	10.00	do	do	8
Steam	120.00		120,000 gallons	Winery	11
Hand		4.25	Good	Dom; st	8
do		4.25	do	do	11
8 wind	23.00	46.00	do	do	12
do	23.50	52.00	do	do	11
Gas			24,000 gallons	Irr; dom	9
Hand	23.00	5 00	Good	Dom	8
8 wind	20.00	75.00	do	do	8
Hand			do	Dom; st	8
do			do	do	12
do	28.00	5.00	do	do	8
do	20.00	6.00	do	do	8
do		4.25	do	do	8
do		6.00	do	do	8
do		5.00	do	do	13
do			do	do	11
do	20.00	4.00	do	do	14
do	16.00	4.00	do	Dom	15
do			do	Dom; st	14
8 wind			do	do	11
Hand		6.00	do	do	14
do		15.00	do	do	10
8 wind		45.00	do	do	8
Hand		5.00	do	do	11
do		4.00	do	do	10
8 wind		50.00		do	11
Hand	25.00	4.90	Good	do	11
do			do	do	11
do		4.00	do	Dom	10
do	30.00	4.00	do	Dom; st	8
do	30.00	4.00	do	do	14
do		4.00	do	Dom	8
do	40.00	4.00	do	do	10
do		4.00	do	do	13
do		6.00	do	Stock	13
do		4.25	do	Dom; st	11
do		4.00	do	do	8
8 wind		65.00	do	do	12
Hand		4.25	do	Dom	16
12 wind	85.00	125.00	do	Dom; st	15
Hand	27.00	4.25	do	Dom	18
do	30.00	8.00	do	do	16
do	12.00	6.00	do	Dom; st	12
Rope			do	do	
do			do	do	
8 wind	22.00	100.00	Good	Dom	13
Hand	29.00	4.25	do	do	11
do		4.00	do	Dom; st	12
8 wind			do	do	12
Wind	45.00	9.00	do	Dom	8

Wells in Kings River delta—Fresno,

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
							Feet.	*Feet.*	*Feet.*	
219	A. B. Butler	14	21	7	.....	B7	.....	9	.....	.....
220	Hughs Richler	14	21	6	1880	B2	40	10	30	CS
221	Fresno Vineyard Co.	14	21	7	.....	B6	.....	9	.....	.....
222	J. Rogers	14	21	8	.....	B8	.....	8	.....	.....
223	Fred Roeding	14	21	2	1887	B7	110	17	93	.....
224	Bonner Vineyard Co.	14	21	11	1885	B8	104	14	90	LHp
225	A. F. Albrecht	14	21	1	1899	B2	54	8	46	CS
226	Judge Risley	14	22	6	1893	B2	90	18	82	CS
227	Fresno Bank	14	22	5	.....	D36	14	10	4	.....
228	John Crol	14	22	9	1892	B6	50	17	33	CSHp
229	M. J. Roeder	14	22	9	1892	B1½	20	16	4	.....
230	Cora Wickersham	14	22	3	1890	B7	.....	14	.....	.....
231	F. P. Wickersham	14	22	3	.....	B2	.....	14	.....	.....
232	Mr. Burness	14	22	3	.....	B6	18	15	3	.....
233	Jno. Snyder	13	22	35	1897	B7	65	20	45	S
234	Chas. Lyman estate	13	22	34	1880	B7	80	0	80	.....
235	R. W. Edmiston	13	22	31	1898	B2	100	5	95	LHpCSG
236	....do	13	22	30	1890	B2	45	18	27	CLHpS
237	.....	13	22	31	1899	B2	.....	0	.....	.....
238	Kutner School	13	22	30	.....	B2	.....	9	.....	.....
239	Victor Marten	14	20	9	1897	B2	82	10	72	S
240	J. H. Hass	14	20	16	1890	B2	70	8	62	.....
241	Mr. Keamey	14	20	7	.....	B	.....	7	.....	.....
242	J. J. Luce	14	19	12	1886	B2	72	8	64	.....
243	Dr. A. E. Small	14	19	12	1890	B2	.....	7	.....	.....
244	Andrew Nelson	14	19	11	1891	B2	60	8	52	CHpG
245	Kearney estate	14	19	10	1890	B2.5	.....	8	.....	.....
246	Dolph Shields	14	19	14	1890	B2	.....	9	.....	.....
247	M. Koller	14	19	15	1890	B2	68	10	58	L
248	F. M. Burnham	14	19	10	1889	B2	73	8	65	LHpCS
249	Maddison School	14	19	12	1897	B2	93	6	87	LHpCG
250	T. H. Burgess	14	19	15	1898	B2	90	8	82	SGC
251	W. W. Underhill	14	19	10	1894	B2	.....	8	.....	.....
252	S. J. Walton	13	19	34	1900	B8	55	10	45	HpCSG
253	Oscar Carlson	14	19	2	1891	B2	35	6	29	LHpC
254	C. D. Smith	14	19	2	1890	B3	70	8	62	SQsS
255	Mrs. H. L. Granger	14	19	2	1891	B2	55	7	48	SC
256	N. H. Fuglsang	14	19	2	1893	B2	80	7	73	.....
257	.....	13	19	35	.....	B2	.....	9	.....	.....
258	Balfour, Guthrie & Co.	13	19	36	1880	B5	30	17½	12½	.....
259	Lew Showyer	14	19	1	1899	B2	.....	8	.....	.....
260	Mrs. C. B. Lyman	14	19	1	1900	B6	97	9	88	LHpSC
261	O. D. Garrison	14	20	21	1888	B2	120	8	112	CG
262	E. Tommasini	14	20	29	1897	B2	82	12	70	LHpS
263	M. Robison	14	20	32	1890	B2	70	10	60	SCG
264	G. C. Cheuvraut	14	20	33	1892	B2	75	6	69	S
265	N. Jansen	15	20	5	1889	B2	50	10	40	S
266	J. Gowanlock	15	20	8	1890	B2	60	10	50	.....
267	.....	15	20	9	.....	B2	.....	12	.....	.....
268	Dickerson	15	20	9	1885	B2	.....	10	.....	.....
269	Mrs. L. Walker	15	20	9	1890	B2	60	10	50	Hp
270	Sonensen	15	20	15	.....	B2	.....	12	.....	.....
271	John Smith	15	20	21	1890	B2	35	10	25	S
272	Bank	15	20	34	.....	B6	50	12	38	.....
273	Stevens & Harland	15	20	33	.....	B6	+50	16	+34	.....
274	....do	16	20	3	.....	B5	+50	15	+35	.....
275	Sacramento Bank	16	20	15	1890	B6	.....	12	.....	.....
276	White	16	20	16	.....	B6	24	16	8	.....
277	Geo. B. Zigler	16	20	22	1899	B6	.....	17	.....	.....
278	David Crawford	16	20	33	1887	B6	80	18	62	LHpS
279	McDonald	17	20	4	.....	B6	39	6	33	.....
280	Geo. Magn	17	20	5	.....	B6	.....	10	.....	.....
281	Lone Sav. Bk. Co	17	20	4	1886	B6	104	10	94	S
282	Lewis Gibbons	17	20	6	1880	B5	118	10	108	LHpSGC
283	John Walker	17	20	7	1880	B8	75	8	67	SQs
284	Fred Coleman	17	20	8	1893	B6	27	7	20	S
285	Elisha Harlon	17	20	18	1890	B5	70	8	62	LCS
286	Lewis Gobbi	17	19	13	1892	Dr7	20	7	13	S
287	Ger. Savings Bk	17	19	13	1893	Dr1½	15	10	5	S
288	Wm. Bullard	17	20	6	.....	B	.....	14	.....	.....
289	Chas. S. Pierce	16	20	31	1890	B6	45	12	33	S
290	Capt. Cuttle	16	19	36	1880	B	75	14	61	.....
291	*Mrs. H. Worswick*	17	19	1	1890	B6	68	10	58	SC
292	*Fred Eaton*	16	19	34	1892	B5	72	15	57	S

ıgs counties—Continued.

hod of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
			Good	Dom; st	8
	$16.00	$4.25	do	do	11
			do	do	10
			do	do	10
d			do	Dom	15
	100.00	100.00	do	Dom; st	12
; hand	25.00	4.00	do	Dom	11
	25.00	4.00	do	Dom; st	10
					10
	55.00	4.00	Good	Dom; st	
	11.00	4.00	do	Dom	12
d			200 gallons	Dom; st	12
		4.00	Good	do	12
	20.00	5.00	Small	do	
	20.00	4.00	Good	do	9
		4.00	do	Dom	8
d	35.00	250.00	do	Dom; st	13
	20.00	40.00	do	Dom	
		4.00	do	Dom; st	
		4.00	do	do	11
d		200.00	do	Dom	17
			do	Dom; st	8
		4.00	do	do	9
			do	do	8
		4.00	do	Dom	18
	25.00	4.00	do	Dom; st	12
		4.00	do	do	15
		4.00	do	do	12
	28.00	66.00	do	do	10
	29.00	4.00	do	Dom	11
i	33.00	38.00	do	do	13
	29.00	41.00	do	Dom; st	11
		11.00	do	do	12
	38.00	47.00	do	do	11
	14.00	4.00	do	Dom	14
i	42.00	50.00	do	Dom; st	13
	22.00	4.00	do	do	20
		11.00	do	Dom	8
		4.00	do	Dom; st	
		4.00	do	do	11
		4.25	do	do	10
i	60.00	270.00	do	do	12
	48.00	4.25	do	Dom	13
		26.00	do	Dom; st	29
		3.00	do	do	20
	25.00	4.00	do	do	26
		4.00	do	do	27
	25.00	4.00	do	do	37
		6.00	do	do	16
		4.00	do	do	89
	24.00	4.00	do	do	28
		4.00	do	do	33
	15.00	6.00	do	do	35
		4.00	do	do	8
		4.00	do	do	
			do	do	24
; hand			do	do	23
		4.00	do	do	11
			do	Dom	11
	65.00	14.00	do	Dom; st	9
		4.00	do	do	13
		5.00	do	do	16
		10.00	do	Dom	15
d	95.00	45.00	do	Dom; st	18
		25.00	Small	Dom	36
id	23.00		Good	Dom; st	45
	70.00	140.00	do	do	10
	5.00	4.00	do	do	14
	4.00	6.00	do	do	20
		4.00	do	do	24
l	45.00		do	do	12
id			do	do	35
	50.00	4.00	Small	do	34
id	51.00		Good	do	85

Wells in Kings River delta—Fresno,

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
							Feet.	*Feet.*	*Feet.*	
293	Mrs. M. J. Hatch	16	19	34	1890	B5	48	15	33	S
294	Mrs. W. M. F. Jenkins	16	19	34	1886	B	130	14	116	
295	Elkhorn School	17	19	10	1896	B6	100	9	91	
296	Mrs. M. J. Hatch	17	19	10	1884	B5	34	10	24	CS
297		16	19	25		B6	25	20	5	
298		16	19	24		B5	+50	18	+32	
299	G. Kowser	16	20	20		B5	42	17	25	
300	Mrs. M. Sloan	16	20	20		B		16		
301	S. F. Bank	16	20	7	1888	B7	+30	20	+10	
302		16	20	7		B5	+21	14	7	
303	S. F. Bank	15	19	36		B6	36	10	26	
304	John Smith	15	19	25		B5		13		
305	John Rottger	15	19	13		B3		8		
306	C. A. Hager	15	19	12	1890	B		8		
307	R. L. Epperson	14	19	36	1894	B2	60	8	52	S
308	R. L. Dunham	14	19	36	1900	B2	44	8	36	SLHp
309	C. J. Smith	14	20	30	1896	B2	+20	7	13	S
310	Mr. Parker	14	19	25	1898	B2	70	6	64	S
311		14	19	15		B8		7		
312	Herman Boyce	14	19	23		B2		8		
313	August Weye	14	19	27	1881	B6	+80	7	73	LSC
314	Burley Bros	14	19	27	1887	B7	65	8	57	S
315	F. Duhring	14	19	34	1887	B6		8		
316	A. Christian	15	19	10	1890	B2	100	9	91	
317	J. W. Creelman	15	19	10	1890	B6		10		
318	Mike Andres	15	19	14	1890	B2		10		SC
319	Geo. Keslang	15	19	14	1891	B2	65	10	55	SC
320		15	19	27		B5	+50	16	+34	
321		16	19	3		B5	30	19	11	
322		16	19	2		B5	20	19½	½	
323	Louis Montego	16	19	1		B5	+50	17	+33	
324	A. B. Trautwein	16	20	6	1891	B2	150	12	138	
325	D. W. Smith	15	20	31	1887	B7	80	12	68	SHp
326		15	20	32		B8	20	15	5	S
327	G. A. Pell	15	20	26	1890	B2	60	12	48	SCHp
328	C. Nelson	15	20	26		B2	54	12	42	
329		15	20	36		B5		10		
330		15	20	36		B2		12		
331	E. R. Haycroft	16	21	6		B6	50	12	38	
332	C. M. Rasmussen	16	21	6	1885			12		
333	Bank	16	20	13		B		14		
334	Wm. Gibson	16	20	24	1890	B6	26	12	14	SLHp
335	J. H Hudson	16	20	25	1880	B5	60	12	48	
336		16	20	25		B5	20+	10	10+	
337	Wm. Gibson	16	21	31		B5		10		
338	Levi Garret	16	22	26	1880	B6		15		
339	Cemetery	16	22	27		B5		15		
340	C. H. Van Horn	16	22	28	1894	B5	82	12	70	SHpC
341	Mrs. S. M. Smith	14	20	15	1899	B2	90	10	80	S
342	F. Burnham	14	20	36	1882	B6	50	8	42	SHpC
343	H. U. Carver	14	20	36		B2		8		
344		15	20	1		B6		10½		
345		15	20	1		B2		10		
346	J. F. Ward	15	20	12	1898	B2	90	8	82	
347	Fresno Nat. Bk	14	20	36	1880	B2	94	8	86	SHpL
348	Y. Maglio	14	20	36	1890	B2		8		
349	J. F. Ca tright	14	20	35		B2		8		
350		14	20	34		B2		8		
351	Geo. A. Coughell	14	20	34	1885	B2	40+	8	32+	SHp
352	Henry Brooks	15	20	3	1885	B2	80			S
353	Jacob Fisher	15	20	3	1885	B6	83	9	74	CS
354	Gus. Johanson	15	20	10	1890	B2		10		S
355	N. M. Nelson	15	20	10		B2	75	10	65	
356	A. Buckland	15	20	11	1881	B5	51	8	43	SHp
357	S. Nelson	15	20	14	1894	Dr[2]	20	8	12	S
358		15	20	23		B1		8		
359	Philip Koekler	15	20	26	1897	B2	60	12	48	
360	Schoolhouse	15	20	25		B2		10		
361		15	21	19			(a)	(a)	(a)	
362	Dexter & Payne	15	21	19	1890	B1½		10		
363	C. B. Scott	15	21	20	1895	B2	60			
364	W. A. Mills	15	21	16	1900	B5	48	14	34	S
365	Mo. Vineyard Co	15	21	9	1890	B4	60	11	49	
366	S. J. Goree	15	21	8	1891	B4	60	10	50	S

[a] Swale water 10 feet below.

and Kings counties—Continued.

of	Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
	12 wind			Good	Dom	8
	Hand		$4.00	do	Dom; st	8
	do			do	Dom	11
	12 wind	$30.00		do	Dom; st	36
	Hand	25.00	5.00	do	do	
	do		5.00	do	do	
	do		5.00	Good	do	11
lk.	Wind			do	do	18
	16 wind			do	Dom	11
	Hand		4.00	do	Dom; st	10
	Hand			Good	Dom; st	11
	do		4.00	do	do	
	do		4.00	do	do	8
	do	24.00	4.00	do	Dom	16
	do	19.00	4.00	do	Dom; st	16
	do		4.00	do	do	23
	do		4.00	do	do	12
	12 wind			do	do	15
	Hand		4.00	do	do	18
	Horse; wind	60.00	120.00	do	do	14
	8 wind	43.00	60.00	do	do	16
	Hand		4.00	do	Dom	16
	14 wind	40.00	95.00	do	Dom; st	28
	Hand			do	do	37
	do			Small	do	20
	do	25.00	4.00	Good	do	20
				do	do	
					do	
				Small	do	
				Good	do	
	8 wind		35.00	do	do	8
	10 centrifugal	100.00		do		9
	Hand		5.00	do	Dom; st	
	10 wind	24.00	47.50	do	do	18
	Hand	22.00	4.00	do	do	10
	do		5.00	do	do	16
	do		4.00	do	do	11
	do	62.00	4.00	do	do	16
	do		4.00	do	do	26
	Wind			do	do	11
	Hand	26.00	4.00	do	Dom	8
	do		4.00	do	do	20
	do		4.00	do	Dom; st	
	8 wind			do	Stock	
	Wind			do	Dom; st	18
	do			do	Irr	11
	10 wind	41.00		do	Dom; st	11
	Hand	36.00	4.00	do	do	
	do		4.00	do	do	12
	do		5.00	do	do	14
	do		4.00	do	do	13
	do		4.00	do	do	13
	do	36.00	4.00	do	do	8
	Wind	37.00	72.00	do	do	10
	Hand		4.00	do	do	9
	do		4.00	do	Dom	
	Wind			do	Dom; st	11
	Hand		4.00	do	do	14
	do	32.00	4.00	do	do	19
	12 wind	70.00	115.00	do	dd	14
	Hand		4.00	do	do	9
	do		4.00	do	do	19
	do	46.00	4.00	do	do	12
	do	8.00	4.00	do	do	8
	do		3.00	do	do	15
	do	25.00	46.00	do	do	10
	do		4.00	do	do	11
	Wind; hand			Good	Dom; st	16
	Hand	25.00	4.00	do	do	14
	do	30.00	4.00	do	do	11
	do	30.00	11.00	do	do	11
	do	24.00	4.00	do	do	11

Wells in Kings River delta—

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strat
							Feet.	*Feet.*	*Feet.*	
367	John Morgan	14	20	16	1890	B2		16		
368	L. A. Gould	14	20	16	1890	B2	80	7	73	
369	T. H. Mallory	14	20	21	1900	B2	69	10	59	SHp
370	W. A. White	14	20	27	1900	B2	57	10	47	CHpSC
371	H. Roff	14	20	27	1897	B2	80	10	70	S
372	do	14	20	33	1880	B8	90	9	81	
373	Richard White	14	20	33	1884	B8	52	6	46	SCG
374	Geo. B. Rowell	15	20	3	1881	B8	94	10	84	S
375	Robt. Boot	15	20	2	1880	B6	90	12	78	CS
376	A. J. Rudy	15	20	2	1898	B2	75	11	64	SC
377		14	21	31		B2		10		
378	A. A. Smith	14	21	32	1890	B2		12		
379	H. M. Eddy	14	21	33	1887	B2	65	9	56	SC
380	R. E. Oliver	15	21	3	1899	B5	29	16	13	S
381	Wylie M. Giffen	15	21	2		B5		12½		
382	do	15	21	12	1880	B		20		
383	J. M. Pugh	15	21	11	1882	B5	42	12	30	SCHp
384	W. O. Edgerly	15	21	13	1880	B6		11		
385	Wm. Dosdon	15	21	24	1894	B2	60	15	45	SCHp
386	J. A. T. Peterson	16	22	7		B5		13		
387	Mrs. C. A. Hammer	16	22	18	1898	B5	40	12	98	SHp
388	S. J. Pelton	16	22	19	1888	B5	86	10	76	
389	Mr. Wilker	16	22	30		B		12		
390	J. C. Bell	16	21	29	1880	B5	54	9	41	S
391	Eschol School	16	22	32	1895	B2	45			CS
392	J. W. Ryce	16	21	36	1886	B5	106	10	96	LS
393	Sacramento Bk	16	22	32	1875	B5	35	10	25	S
394	do	17	22	4	1875	B5	50	10	40	
395	do	17	22	4	1888	B5	50	15	35	
396	Laguna de Tach	17	21	3	1895	B5	107	12	95	
397	S. P. Co	16	21	36	1891	B3	50	20	30	HpS
398	Mrs. M. A. Cowan	16	22	32	1895	B2		15		S
399	John Clark	16	21	28		B5		14		
400	Larse Anderson	16	21	21	1888	B5	60	21	39	SHp
401		16	21	20		B1½		13		
402	W. T. Prather	16	22	17	1880	B6		15		SHpC
403	A. J. Allen	16	21	10	1870	B5	90	16	74	SCHp
404	T. C. Clayton	16	21	3	1893	B5	102	15	87	S
405		15	21	33		B		15		
406	F.-C	15	21	37		B		16½		
407	F. P. Wall	15	21	32	1894	B1½	60	17	43	SHp
408	A. Proctor	15	21	32		B2		13		
409		15	21	20		B2		17		
410	Charley Woods	15	21	9	1885	B5		13		
411	Ben Swanson	15	21	9	1890	B2		16		
412	A. T. Wilkinson	15	21	5	1880	Dr1	30	18	12	SCHp
413		14	21	29			(a)	(a)	(a)	
414	S. A. Tyler	14	21	32	1900	B8	75	15	60	SCGHp
415	A. Hall	14	21	30	1880	B8		14		
416	Chas. Preuss	14	21	19	1892	B5	38	12	26	HpCS
417	Fresno L. and S. Bk	14	20	14	1880	B6	65	8	57	S
418	Estrella de Ora Drying Co.	14	20	13	1891	B2	75	5	70	CS
419	St. George Vineyard	14	21	17		B8		10		
420	M. E. Sherman	14	21	17	1899	(2 wells)	40	10	30	SHp
						B6	120		110	
421		14	21	21		B8		13		
422	Lone Star School	14	21	22	1897	B2	60	12	48	SG
423	A. C. Funch	14	21	23	1895	B2	80	12	68	SC
424	A. Malter	14	21	27	1894	B2		12		
425		15	21	10		B2		10		
426		15	21	9			(b)	(b)	(b)	
427	A. R. Brown	15	21	10	1900	B5	54	12	42	CS
428	W. R. Shannon	15	21	14	1890	B5	52	11	41	CSHp
429	A. Harris	15	21	23	1881	B5	100+	14	86+	HpS
430	Mrs. C. E. Gower	15	21	27	1894	B5	85	14	71	SHpC
431	M. Leeper	15	21	34	1887	B2	60	14	46	SHpC
432	W. J. Zimmerman	15	21	34	1899	B6	28	12	16	SL
433	Fresno L. and S. Bk	15	21	34	1888	B5	100+	12	88+	
434	J. B. Galbreath	15	21	28		B6		14		
435	J. C. Long	15	21	28	1892	B	80	12	68	SHp
436	Len Lhung	15	21	15	1899	B	90	15	75	
437	H. A. Ross	15	21	2	1898	B5	60	12	48	SG
438		15	21	2-3			(c)	(c)	(c)	

[a] *Slough water 15 feet below.*

[b] Swale water 10 feet below.

nd Kings counties—Continued.

Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Hand		$4.00	Good	Dom; st	12
Wind	$40.00	150.00	do	do	13
8 wind	28.00	300.00	do	Dom	13
do	225.00	45.00	do	Dom; st	73
Hand	32.00	4.00	do	do	15
	80.00		do	do	16
Hand	52.00	4.00	do	do	9
Wind	94.00		do	do	18
Hand	90.00	4.00	do	do	15
do			do	do	12
do		4.00	do	do	21
Turbine			do	Dom	15
Hand	65.00	25.00	do	Dom; st	11
do	21.00	4.00	do	do	16
do		5.00	do	do	12
do			do	do	27
Wind	28.00	14.00	do	do	13
Hand		4.00	do	do	26
8 wind	27.00	40.00	do	do	11
Hand		12.00	do	do	
do	40.00	12.00	do	do	11
do			do	do	24
do		4.00	do	do	23
10 wind	50.00		do	Stock	21
Hand	18.00	4.00	do	Dom	9
do	36.00	4.00	do	Dom; st	
do	35.00	4.00	do	do	10
do		4.00	do	Dom	23
do	37.00	5.00	do	Dom; st	30
do		4.00	do	Dom	8
do		4.00	Small	Dom; st	8
do		4.00	Good	do	8
do		4.00	do	do	14
do	30.00	4.00	do	do	14
Hand		4.00	Good	Dom; st	13
8 wind		58.00	do	do	9
do	90.00	60.00	do	do	10
Hand	51.00		do	Dom	9
do		4.00	do	Dom; st	13
do			do	do	16
do			do	do	19
do		4.00	do	do	12
do		4.00	do	do	
do		4.00	do	do	14
Wind			do	do	20
do	15.00	40.00	do	do	12
Wind			Good	Dom; st	15
Hand		4.00	do	do	8
do	19.00	80.00	do	do	11
Wind	65.00		do	do	9
Hand			do	Dom	12
do		6.00	do	Dom; st	12
Steam	206.00	1,300.00	1,292,633 gallons	Irr	9
Hand		5.00	Good	Dom; st	15
do	24.00	4.00	do	do	13
do	25.00	5.00	do	do	15
8 wind			do	do	16
Hand			do	do	12
Wind	30.00	4.00	Good	Dom; st	16
Hand	26.00	11.00	do	do	12
do	75.00	11.00	do	do	12
10 wind	75.00		do	do	9
8 wind	40.00	117.50	do	Dom	9
Hand	17.00	3.25	do	Dom; st	9
do		3.25	do	do	14
Wind			do	do	8
do	60.00	100.00	do	do	17
do			do	Dom	12
Hand	45.00	4.00	do	Dom; st	25

[a] Swale water 15 feet below.

Wells in Kings River delta—Fresno

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
							Feet.	*Feet.*	*Feet.*	
439		14	21	35		B2	34	16	18	
440	M. Wash	14	21	27		B5		13		
441	M. J. Driver	14	20	22	1883	B7	40	15	25	LHpSC
442	E. F. Ball	14	20	14	1893	B6	85	13	62	
443	T. I	14	20	14		B		12		
444	Mrs. F. C. Ketchum	14	20	13	1890	B2	60	12	48	
445	C. N. Brenenfeld	14	21	20	1895	B2	80	9	71	SCHp
446	Jas. Rutheford	14	21	21	1891	B2	100	9	91	CHpS
447	I. D. Garrison	14	21	29		B2		8		S
448	J. W. Scott	14	21	29	1895	B2	60	7	53	S
449	E. R. Bates	14	21	19	1890	B2	82	10	72	
450	J. H. La Ru	14	21	32	1886	B5	50	8	42	SC
451	John Oed	14	21	33	1885	B		10		
452	W. H. Martin	14	21	26	1890	B2		14		
453		14	21	36			(a)	(a)	(a)	
454	Mrs. J. J. Owen	14	22	31	1898	B5	48	13	35	SC
455	D. W. Butler	14	22	31	1898	B5	60	11½	48½	SHpC
456	Dr. A. D. Wilson	15	21	12		B5		11		
457	F. Lemon	15	21	13		B5		13		
458	Mr. Scott	15	21	13		B		15		
459	T. M. Boyd	15	22	17	1881	B5	60	13	47	LSC
460	Geo. West & Son	15	22	29	1900	B8	120	16	104	SCHp
461	Mrs. L. Vance	15	22	31	1885	B5	75	15½	59½	S
462	C. T. Pierson	16	22	6	1890	B2	80	12	68	
463	S. Y. Gordon	16	22	7	1882	B5	108	10	98	SHpC
464	J. C. Hinkle	16	21	11	1890	B5	40	8	32	SCHp
465	D. Shiflet	16	21	10	1890	B5		12		S
466	T. E. Finerty	16	21	4	1885	B5	80	16	64	SCHp
467	H. Craven	16	21	9	1894	B5	50	14	36	S
468		16	21	7–8			(b)	(b)	(b)	
469	Harry Weber	16	21	18		Dr1¼	12	10	2	S
470	Sacramento Bank	16	21	18	1890	B6	30	10	20	S
471	H. Maguire	16	21	19		B5		8		S
472	David Heishie	16	21	20	1888	B5		8¼		S
473	J. J. D. Barish	16	21	20	1894	Dr¼	16	8	3	S
474	J. G. Burnett	16	21	30	1890	B4	25	7	13	SC
475		16	21	31		B5	20	15	5	S
476	Roza Breiza	16	21	29		B5		10		
477	Lee Burton	16	21	28	1880	B4	70	10	60	
478	Martin Elder	16	21	35	1898	B8	52	8	44	SCHp
479	T. G. Martin	16	21	26	1899	B10	50	8	42	LHpSC
480	Will Pickard	16	21	36	1892	B5		10		
481		16	21	24		B5		10		
482	C. S. Campbell	16	21	24	1882	B5	60	9	51	SCHp
483	Sacramento Bank	16	21	12	1880	B5	75	12	63	SCHp
484	Jno. H. Hoffman	16	21	1	1894	B5	35	12	23	S
485	C. E. Roberts	16	21	1	1888	B5	60	14	46	SCHp
486		15	21	35–36		⅛ by ⅛ mi.	(c)	(c)	(c)	
487	Mr. Vogel	15	21	35		B2		15		
488	Edwin Bullock	14	20	25	1899	B	70	12	58	SCHp
489	F. G. J. Schmidt	14	20	23	1896	B2	40	10	30	
490		15	21	6			(d)	(d)	(d)	
491	F. H. Mills	15	21	5	1890	B5		13		
492		15	21	7			(a)	(a)	(a)	
493	J. V. Lamore	15	21	18	1885	B2	60	12	48	SHp
494	J. B. Perrin	15	20	12	1882	B5	22	13	9	SLHp
495	T. E. Elliott	15	21	18	1890	B2		12		
496	Chas. K. Kirby	15	21	18	1882	B5		12		
497	Mr. Madden	15	21	29	1885	B5	100	12	88	
498	Jno. K. Kennedy	15	21	30	1894	B5	96	13	83	SHp
499		15	21	30			(c)	(c)	(c)	
500	Harland & Stevens	15	21	31	1885	B5		14		
501		16	21	6			(d)	(d)	(d)	
502	Thos. Hansen	16	21	5	1893	B5		14		
503		15	21	32			(a)	(a)	(a)	
504	Robt. E. Hall	16	21	4	1890	B5	100	14	86	HpCS
505		16	21	4–5 W. ½			(c)	(c)	(c)	
506	Sacramento Bank	16	21	8	1892	B5		20		
507	Terry School	16	21	10		B5		10		
508	Mr. Johnson	16	21	10		B5		10		
509	Jno. Reynolds	16	21	14	1892	B5	60	9	51	SCHp

[a] Swale water 12 feet below.

[b] Swale water 15 feet below.

id Kings counties—Continued.

Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Hand			Good	Dom; st	
do		$4.00	do	do	12
do		12.00	do	do	13
Wind			do	do	13
Hand		4.00	do	do	12
do	$24.00	4.00	do	do	8
do	25.00	5.00	do	do	9
do	40.00	3.00	do	Dom	11
do		4.00	do	Dom; st	16
do	24.00	3.00	do	do	13
8 wind		250.00	do	do	16
10 wind	40.00	75.00	do	do	19
			do	do	13
Hand		3.25	do	do	15
Wind	26.00		Good	Dom; st	16
Hand	23.00	3.25	do	do	21
Wind			do	do	24
Hand			do	do	10
do		4.00	do	do	15
do	60.00	11.00	do	do	
Steam	132.00		120,000 gallons	Winery	8
Hand		3.25	Good	Dom; st	15
do		3.25	do	do	25
do	86.00	12.00	do	do	10
			do	do	11
Hand			do	do	14
Hand	80.00	3.25	do	do	12
do	25.00	3.25	do	do	10
Hand		3.25	Good	Dom; st	39
do		3.25		do	10
Horse		6.00	Good	do	26
			Small	Dom	
Hand	4.00	3.25	Good	Dom; st	8
do		4.00	do	Dom	13
do		5.00	Small	Dom; st	16
Wind		3.25	Good	do	26
Hand	40.00	3.00	do	do	8
Steam	52.00	436.00	323,158 gallons	Irr	34
do	42.00	436.00	323,158 gallons	do	10
Hand		3.00	Small	Dom; st	12
Wind		4.00	Good	do	18
do			do	do	12
Hand		3.50	do	do	10
do	20.00	4.00	do	do	15
do		3.50	do	do	18
Hand		3.25	Good	Dom; st	8
8 wind		35.00	do	do	11
Hand	20.00	3.25	do	do	15
Hand		3.25	Good	Dom; st	20
Hand	25.00	3.25	Good	Dom; st	12
8 wind		45.00	do	do	10
Hand		3.00	do	do	20
16 wind			do	do	15
Wind		70.00	do	do	14
Hand	57.00	3.25	do	do	28
Hand		4.00	Good	Dom; st	11
Hand		3.25	Good	Dom; st	4
8 wind		49.00	Good	Dom; st	11
Wind			Good	Dom; st	39
Hand		3.25	do	do	16
do		3.00	do	do	14
do		3.25	do	do	24

[a] Swale water 14 feet below.

[d] Swale water 13 feet below.

Wells in Kings River delta-

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Str
							Feet.	*Feet.*	*Feet.*	
510		16	21	14			(a)	(a)	(a)	
511	J. D. Griffey	16	21	13		B5		12		
512	J. Hamilton	16	21	24	1899	Dr2	22	10	12	SHp
513		16	21	26			(b)	(b)	(b)	
514	Central School	16	21	26		B5		10		
515	Dick Butler	16	21	22	1888	B5	30	11	19	SHpC
516	E. R. Holton	16	21	28	1882	B5	30	7	23	
517	Mrs. M. L. Viere	16	21	15	1882	B5		9		
518	J. F. Crowder	16	21	24	1894	B5	94	10	84	S
519	D. Patton	16	22	9	1880	B5	100	11	89	LS
520	J. B. Fontaine	16	22	4	1896	B5	52	10	42	S
521		16	22	3-10			(c)	(c)	(c)	
522	Percy Fowler	16	22	3	1880	B5		14		
523	Sam. L. Hogue	16	22	12	1885	B5		11		HpCS
524	Prof. Heald	16	23	7	1880	B5		12		SHp
525		16	23	8		B5		12		
526	Prof. Heald and Heley	16	23	6	1897	B5		14		SHp
527	Gust Almgren	15	23	33		B5		33		
528	Gust Stromberg	16	23	4	1899	B6	85	30	45	SHp
529	M. E. Stanton	15	23	32	1888	B5	62	40	22	HpS
530	Jno. Holnberg	15	23	33	1880	B6	93	50	43	HpCSG
531	T. L. Reed	15	23	32	1889	B5		60		LHpCS
532	do	15	23	27	1889	B6	75	45	30	LHpCS
533	Burris Bros	15	23	26		B5	23	21	2	HpC
534	S. T. Curtes	15	23	35		B5		18		CHp
535	A. Winters	16	23	13	1898	D36	12	6	6	
536	Mrs. A. R. Orr	16	23	12	1890	B5	80	15	65	
537	Mr. Dittman	16	24	7		B		10		
538	J. W. Roberts	16	24	8	1900	B5	70	10	60	CSHp
539		16	24	5		B8	50	8	42	
540	Mrs. A. R. Orr	16	24	4		B		10		
541	K. Gregory	16	24	5	1887	B5	84	12	72	CHpS
542	L. Pederson	15	24	33	1900	B5	75	12	63	CHpS
543	Cal. F. & L. Co	15	24	29		B5	50	13	37	
544	J. S. Jones	15	24	19		B8		17		
545	R. M. Wilson	15	24	19	1891	B7	64	15	49	HpCS
546	J. T. Mance	15	24	18		B5	15	(d)	(d)	
547	Ger. L. & S. Bank	15	23	13	1886	B5	58	22	36	
548	A. L. Holmes	15	23	24		B5	38	29	9	
549	Purington	15	23	24	1890	B5		24		HpS
550	Joe Housley	15	23	27	1890	B6	71	35	36	HpSC
551	J. H. Harden	15	23	15	1885	B6	84	50	34	LHpS
552	P. Legure	15	23	15	1885	B5	85	40	45	HpCS
553	Fink School	15	23	10	1900	B5	100	42	58	HpCS
554	San Francisco Bank	15	23	11		B5		40		CHpS
555	Fisher	15	23	14		B5	80	35	45	
556	Frank South	15	23	14		B5	25	(d)	(d)	
557	F. Fisher	15	23	12		B8				
558	Victor Franzon	15	23	12	1881	B5	60	32	28	HpCS
559	Gosliner Bros	15	24	6		B				
560	do	15	24	7	1885	B7	80	25	55	HpSC
561	Sacramento Bank	15	24	6		B7	30	12	18	
562	Sweets Place	14	24	32		B6		13		CHpS
563	Mr. Martinez	14	24	33	1886	B5	97	12	85	
564	Mrs. Merrit	14	24	29	1885	B6	40	20	20	
565	Alta District	14	24	30		B5	100	20	80	
566	Jake Eppinger	14	23	26	1897	B6	90	27	63	HpCS
567	Mrs. J. D. Reese	14	23	9	1899	D	18	14		G
568	S. W. Lewis	14	22	14	1898	B12	48	18	30	LG
569	N. L. Durgin	14	22	22	1890	Dr2		20		
570	W. H. Spitler	14	22	32		B5	25	16	9	
571	C. Gravani	14	22	17	1898	B2		12		
572	Fruitvale estate	14	19	8	1894	B2	60			
573	I. C. Barman	14	19	18	1893	B1½	85	6	79	
574	Mat. Asmussen	14	18	12	1881	B2	70	8	62	
575	J. C. Appley	14	18	14	1894	B2		8		S
576	John Condon	14	18	26	1894	B2		8		S
577		14	18	26		B2	21	9	12	
578	Geo. P. Thornton	14	19	30	1893	B2	80	8	72	
579	Mrs. G. F. Thornton	14	19	29	1893	B2	90	10	80	HpSC
580	(On county road)	14	19	28		B7		7		
581	Burley Bros. & McNeil.	14	19	22		B2		5		S

[a] *Lagoon* water 11 feet below.

[b] Swale water 10 feet below.

nd Kings counties—Continued.

Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Hand		$8.25	Good	Dom; st	12
do	$10.75	3.25	do	do	8
Hand		3.25	Good	Dom; st	13
Wind		4.00	do	do	9
Hand			do	do	8
14 wind			do	do	15
8 wind		50.00	do	do	14
Hand			do	do	8
do		3.50	do	do	8
Hand		4.50	Good	Dom; st	8
do		3.50	do	do	17
Wind			do	do	24
Hand			do	do	17
do		12.00	Small	do	14
do			Good	do	16
do	67.00	11.00	do	do	14
Wind			do	do	12
Hand		100.00	do	do	15
do			do	do	12
Wind			do	do	26
Hand		4.25	do	do	12
do			do	do	11
Rope			do	do	
Hand; horse	80.00		do	do	8
Hand			do	do	13
do	36.00	3.50	do	do	14
do		5.00	do	do	12
do		5.00	do	do	31
do	40.00	3.50	do	do	13
do	30.00	3.50	do	do	12
do		3.50	do	Dom	14
Wind			do	Dom; st	
do			do	do	12
Water; hand		6.00	do	do	12
12 wind			do	Stock	11
Hand		5.00	do	Dom; st	12
do			do	do	19
Wind			do	do	13
do	84.00	100.00	do	do	16
8 wind	80.00	70.00	do	do	14
Hand			do	do	10
do			do	do	14
14 wind			do	do	10
8 wind		47.00	do	do	11
Wind			do	Stock	8
do			do	Dom; st	12
Hand			do	do	10
12 wind	80.00		do	do	13
Hand		4.00	do	do	13
do		5.00	do	do	
do	97.00	3.25	do	do	13
8 wind			do	do	17
Hand		4.25	do	do	8
Wind			do	do	12
Hand		12.00	do	do	11
Wind			do	do	9
8 wind		47.00	do	do	18
Hand			do	do	11
do		3.50	do	do	
Wind			do	do	8
Hand		3.50	do	do	13
do	21.00	3.25	do	do	
do			do	do	19
do		5.00	do	do	20
			do	do	
Wind	24.00	47.00	do	do	16
do	25.00	89.00	do	do	21
Hand		3.25	Good	Dom; st	32

[a] *Swale water 12 feet below.*

[d] No water.

Wells in Kings River delta-

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well. Feet.	Depth to water. Feet.	Depth of water. Feet.	Str
582	Mr. Harris	13	19	26	.....	B5	17	14	3	.....
583	Lafayette Pearson	13	19	26	1892	B2	.....	16	.....	HpCS
584	Mr. Williams	13	19	29	.....	B7	35	21	14	.....
585	S. H. Crane	13	19	30	1898	B7	.....	16	.....	SHp
586	.....	13	18	25	1898	B2	.....	19	.....	.....
587	Kennedy & Owen	13	18	25	.....	B5	40	16	24	.....
588	California Bank	13	18	23	1898	B5	100	22	78	.....
589	Mrs. Thornton	13	19	19	1888	B6	60	20	40	.....
590	.....	13	19	17	.....	B7	.....	.....	.....	.....
591	.....	13	19	17	.....	B5	.....	.....	.....	.....
592	Ed. Ferguson	14	21	12	.....	B2	.....	10	.....	.....
593	Sierrng Bros	14	21	13	1892	B5	90	10	80	LHpSC
594	P. M. Hart	14	22	19	.....	B2	.....	10	.....	SGS
595	David Antres	14	22	19	1898	B5	.....	10	.....	.....
596	W. R. Wilson	14	22	21	.....	B5	.....	18	.....	.....
597	.....	14	22	29	.....	.....	(a)	(a)	(a)	.....
598	.....	14	22	26	.....	.....	(a)	(a)	13	.....
599	Will McKenzie	14	22	26	.....	Dr?	54	12	42	.....
600	Bethel schoolhouse	14	22	34	1888	B5	.....	11	.....	.....
601	J. A. Roberts	15	22	3	1892	B6	85	14	71	.....
602	M. A. Colton	14	22	35	1900	B5	58	.....	.....	CS
603	H. O. Marshall	15	22	11	.....	B5	.....	14	.....	.....
604	.....	15	22	3	.....	Swale	.....	13	.....	.....
605	A. J. Wells	15	22	9	1883	B5	52	12	40	S
606	H. S. Hulbert	15	22	9	1879	B5	72	10	62	S
607	J. J. Wiley	15	22	15	.....	B5	.....	16	.....	.....
608	Shafer Bros	15	22	14	1886	B5	70	16	54	S
609	D. C. McClarly	15	22	25	1881	B6	65	15	50	CHpS
610	H. White	14	22	27	1892	Dr?	32	10	22	S
611	G. L. Traber	15	22	26	1877	B5	60	15	45	.....
612	Mathias Thomson	15	22	35	1892	B5	.....	14	.....	.....
613	H. F. Graper	16	22	2	1888	B6	48	13	35	CS
614	Helge Lee	16	22	14	1896	B5	.....	13	.....	.....
615	Frank Hanson	16	22	13	1889	B5	40	15	25	S
616	W. H. Seward	16	22	13	1893	B5	45	15	30	LSHp
617	Charles Strid	16	22	23	1892	B5	30	12	18	GS
618	Wells Anderson	16	22	28	1888	B5	40	20	20	HpCS
619	E. S. Boot	16	23	30	1888	B5	52	25	27	CHpS
620	Mrs. A. Stober	16	23	19	1889	B5	67	17	50	LHpCS
621	A. B. Clark	16	23	19	.....	.....	.....	22	.....	.....
622	S. F. L. & S. Assn	16	23	18	1886	B5	70	15	55	HpCS
623	N. J. Shadle	16	23	18	1891	B5	60	20	40	HpCS
624	N. J. Layton	16	23	8	1884	B5	64	20	44	HpCS
625	G. Bordson	16	23	6	1888	B5	40	14	26	LHpSC
626	J. A. Beall	15	22	25	1900	B5	.....	17	.....	LHpSC
627	J. M. Marshall	15	23	29	1881	B6	116	30	86	HpCS
628	Martin Miller	15	23	30	1880	B5	70	20	50	LHpCS
629	J. A. Milton	15	23	20	1891	B5	68	28	40	LHpS
630	N. Boysen	15	23	20	1891	B8	55	25	30	HpS
631	Milton M. West	15	23	21	1891	B5	45	40	5	S
632	Sacramento Bank	15	23	19	1885	B5	53	30	23	HpS
633	C. O. Love	15	23	18	1885	B6	30	25	5	HpS
634	E. L. Jediker	15	22	13	1884	B5	59	25	34	HpCS
635	.....	15	23	7	.....	B6	.....	45	.....	.....
636	S. P. R. R. Co	15	23	8	.....	B5	.....	30	.....	.....
637	Kimble estate	15	23	7	.....	B6	60	35	25	SCHp
638	M. Bassett	18	21	14	1898	B5	44	10	34	SC
639	Aug. Weihe	14	20	5	1897	B2	35	7	28	LHpSC
640	O. J. Ransom	14	20	6	.....	B	.....	9	.....	.....
641	Geo. Roeding	13	20	31	1900	B5	93	12	81	CHpS
642	Balfour, Guthrie & Co.	13	19	25	1888	B5	.....	24	.....	.....
643	.....	13	19	35	.....	B8	.....	17	.....	.....
644	Judson & Stutson	13	19	6	1883	B7	115	60	55	.....
645	California Bank	13	19	11	1897	B5	83	38	45	LHpSC
646	do	13	19	11	1882	B7	112	38	74	.....
647	J. E. Rawlins	19	21	1	1882	B6	42	10½	31½	HpS
648	Philips estate	19	22	7	1895	B5	40	10	30	S
649	R. S. Wait	19	21	13	1878	B6	40	10	30	CS
650	C. H. Watson	19	22	19	1893	B5	45	8	37	CHpS
651	Cal. S. & L. Assn	19	21	25	1880	B6	55	9	46	CS
652	A. P. Redding	19	21	36	1889	B10	783	(b)	.....	SCCS
653	A. Onesti	18	21	36	.....	B5	.....	11	.....	.....
654	A. L. Cressy	18	21	35	1884	B	25	10	15	.....

[a] Swale water 13 feet below.

d Kings counties—Continued.

Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Hand			Good	Dom; st	
do		$8.00	do	do	10
Lift			do	do	11
Hand		6.00	do	do	4
do		3.50	do	do	12
do		3.50	do	Stock	17
8 wind	$100.00	50.00	do	Dom; st	32
Wind			do	do	12
Hand		3.50	do	do	13
Wind			do	do	12
Hand		3.50	do	do	18
Wind	90.00	65.00	do	do	15
8 wind		56.00	do	do	14
Hand		3.50	do	do	16
do		3.25	do	do	19
Hand		3.00	Small	Dom; st	14
Lift			Good	Dom	14
Hand		3.00	do	Dom; st	8
do	30.00	3.50	do	do	10
do		3.50	do	do	12
Hand	30.00	3.00	Good	Dom; st	14
8 wind	79.00	200.00	do	do	11
Wind			do	do	8
Hand		3.50	do	Stock	19
do		3.25	do	Dom; st	8
do	4.50	3.50	do	do	8
do		3.50	do	do	13
do		3.50	do	do	18
do	36.00	3.50	do	do	32
do		3.50	do	do	9
do	30.00	3.50	do	do	31
do	35.00	15.00	do	do	33
do	22.00	3.50	do	do	15
do	30.00		do	do	12
do		11.00	do	do	11
do	67.00	14.00	do	do	14
do		9.00	do	do	11
do	52.00	3.50	do	do	28
do	44.00	120.00	do	do	17
Wind; hand			do	do	21
12 wind		200.00	do	do	29
Wind			do	Dom	15
12 wind	116.00	42.00	do	Dom; st	11
8 wind	70.00	46.00	do	do	13
do	48.00	55.00	do	do	17
Hand			do	do	29
do			do	do	11
do	53.00	11.00	do	do	11
do		5.00	do	do	11
Wind	59.00	158.00	do	do	16
8 wind		40.00	do	do	12
Hand			do	Stock	10
14 wind			do	Dom; st	8
Hand	22.00	4.00	do	do	9
do	8.80	3.50		do	12
14 wind; hand			Good	do	8
8 wind	73.00	50.00	do	do	12
16 wind			do	do	11
Hand		6.00	do	do	14
Wind			do	do	28
8 wind	58.00		do	do	38
do		53.00	do	do	16
12 wind	42.00	150.00	do	do	14
Hand		6.00	do	do	94
do			do	Dom	40
do			do	Dom; st	54
do	55.00	7.00	do	Dom	19
	2,000.00		488,920 gallons	Dom; irr	14
Hand		4.00	Good	Dom; st	12
8 wind	25.00	50.00	do	do	16

[b] Flows.

Wells in Kings River delta—F

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata
							Feet.	*Feet.*	*Feet.*	
655		19	21	11		Dr1¼		9		
656		19	21	14		B5		10		
657	Fred Ward	19	21	26		B5		9		
658	Silvan Fereira	19	21	26		B4		9		
659	Jno. Bowers	19	21	36	1894	B9	800	(a)		CS
660	W. S. Burr	20	21	2	1900	B5	44	16	28	CS
661	Mrs. J. Hide	20	21	12		B		15		CS
662	W. V. Walker	18	21	34	1890	B5	35	10	25	
663	Maria Reynolds	18	21	33	1885	B5	36	12	24	CS
664	S. Badger	18	21	32		B5		11		SC
665	Mrs. M. Camp	18	21	30	1880	B5	32	10	22	CS
666	W. J. Weir	18	20	36	1890	B5	40	10	30	SC
667	Mrs. H. Bryant	18	20	30	1880	B5	50	12	38	CS
668	T. L. Hanna	18	20	26	1900	Dr2	42	7	35	CS
669	M. P. Hatch	18	20	27	1882	B5	34	12	22	CSL
670	G. E. Lathan	18	20	33	1897	B5	132	1+	131	CS
671		18	20	33	1900	B5		3½		CS
672	R. M. Coon	19	20	4	1877	B8	52	8	44	SC
673	James Wright	19	20	10	1892	B6		8		SC
674	J. J. Moss	19	20	10	1888	B6	108	4	104	SC
675	Jno. Hunlen	19	20	16		B7	100+	(a)		SC
676	R. W. Dougherty	19	20	15	1892	B5	139	3½	135½	SL. SiltC.
677	Mrs. E. Cory	19	20	14	1882	B6	33	8	25	SCS
678	Fred Jennings	19	20	13	1883	B6	36	10	26	CS
679	J. F. Florey	19	20	13	1885	B5	40	8	32	CS
680	G. E. Shore	19	21	18	1889	B7	40	10	30	SC
681	L. R. Love	19	21	20	1890	B5		12		S
682	W. W. Parlin	18	21	15	1880	B5		6		
683	Martin Roberts	19	21	22	1882	B5	25	12	13	SC
684	H. N. Hogle	18	21	25	1880	B4	75	10	65	CS
685	Wm. Hogle	18	21	23	1897	Dr2	100	8	92	CS
686	Mary White	18	21	22	1890	B5	57	8	49	CS.[b]
687	Mike Dutra	18	21	22	1889	B5	50	9		CS.[b]
688	Geo. I. Richie	18	21	21	1895	B5		10		CS.[b]
689	H. E. Ayers	18	21	30	1880	B5		8		CS.[b]
690	Mr. Page	18	20	24	1900	B5	24	8	16	CS
691	J. L. Kurtz	18	20	26	1896	B5	28	7	21	CS
692	J. D. Patterson	18	20	22	1892	B5	106	3	103	CS
693	J. Sutherland	18	20	28	1894	B2	530	(a)		CS.[b]
694	Frank Sharples	18	20	16	1898	B5	170	10	160	SC
695	R. H. Kearns	18	20	27	1894	B2	56	8	48	SC
696	J. Sutherland	18	20	15	1899	B5	96.5	3	93.5	CS.[b]
697		18	20	12		B5		12		
698	T. P. Sutherland	18	20	13		B5		10		
699	W. A. Long	18	21	18		B5	33	6	27	SC
700	C. Lathan	18	21	18	1890	B5	40	6	34	CS
701		18	21	17	1898	B		8		SC
702	Kimball, trustee	18	21	9		B		8		SC
703	Mrs. M. A. Haws	18	21	9	1891	B5	50+	8	42+	SC
704	Jno. Wynrck	19	21	2	1884	B7	608	(a)		SC
705	Mrs. M. Andrews	19	21	10	1882	B5	60	10	50	SC
706	J. R. Mullinix	19	21	14	1880	B6	40	12	28	SC
707	W. S. Slavin	19	21	23	1895	B5	35	12	23	CS
708	Jno. Sigler	19	21	26	1892	B5	65	12	43	SC
709	M. P. Rose	19	21	26	1890	B4		10		
710	A. M. Stone	19	21	34		B5		14		
711	W. Burr	20	21	10		B7		13		
712	C. Paddock	20	21	4		B5	35	13	22	SC
713	M. F. Mines	20	21	4	1891	B5	83	14	69	SC
714	Mussel Slough C. and I. Co.	20	21	5		B5		21		
715	T. J. Smith	19	21	31	1899	B6	38	12	26	CS
716	E. G. Sellers	19	20	36	1895	B5	52	12	40	CS
717	E. Jacobs	20	20	2		B9		(a)		
718	W. Blevins	19	20	26	1892	B6	40	10	30	SC
719	John Hereford	19	20	22	1885	B5	40	11	29	
720	Joe Whiteside	19	20	26	1898	B6	114	8	106	CS
721		19	20	35		D48	10	7	3	CS
722	Judge Shores	19	20	25	1890	B6		10		
723	D. R. Nidiffer	19	21	19	1875	B5	37	10	27	SC
724	H. V. Woodgate	19	21	29		B5		10		
725	Geo. W. Houston	19	21	21	1890	B5	34	12	22	SLSC
726	P. C. Eccles	18	21	35	1891	B4	40	10	30	
727	F. E. Wood	19	21	3	1890	B5	50	8	42	

[a] Flows.

ings counties—Continued.

thod of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
d			Good	Dom	15
lo		$3.25	do	Dom; st	15
irbine		130.00	do	do	31
d			do	do	23
	$1,600.00		do	do	16
nd	22.00	31.50	do	do	92
d		5.00	do	do	12
lo		3.25	do	do	14
lo		6.00	do	Dom	9
lo		3.00	do	do	11
nd	32.00	53.00	do	do	15
d			Small	do	13
lo	50.00	4.00	Good	do	17
lo	21.50	4.50	do	Dom; st	8
lo	20.00	4.00	do	Dom	9
lo	69.00	4.00	do	Dom; st	15
lo		4.00	do	do	23
d				do	24
d			Good	do	13
lo			do	do	30
			5,789 gallons	Dom	72
d	108.00	4.00	Good	Dom; st	59
lo	17.00	3.25	do	Dom	14
lo	17.00	4.00	do	do	14
d; hand			do	do	19
lo			do	Dom; st	32
e			do	do	10
d		3.00	do	Dom	17
lo		3.00	do	do	59
lo	30.00	4.00	do	Dom; st	11
lo	50.00	4.50	do	do	15
	28.50		do	do	9
d		4.00	do	Dom	8
lo		4.00	do	Dom; st	10
lo		3.00	do	do	9
lo		4.00	do	do	37
lo			do	Dom	13
lo	99.00		do	do	14
sian			482 gallons	Dom; st	29
d		4.00	Good	do	13
lo	28.00		do	do	10
lo	65.00	3.00	do	do	12
lo		3.00	do	Dom	8
d; hand			do	Dom; st	13
d	16.00	4.00	do	do	12
ind	20.00	65.00	do	do	11
d		3.00	Good	Dom	11
lo			do	do	11
			do	do	9
	1,333.00		32,166 gallons	Dom; st	21
d		4.00	Small	Irr.; dom	12
lo	41.00	4.00	Good	Dom	9
nd		4.00	do	Dom; st	75
d	33.00	3.00	do	Dom	13
lo		4.00	do	do	11
lo		6.00	do	Dom; st	12
lo		4.00	do	Dom	110
lo		3.50	Small	Dom; st	31
lo		3.00	Good	do	32
(a)					
	18.00	4.00	Good	Dom; st	31
d		3.50	do	do	33
			6,433 gallons	do	29
d	30.00	3.00	Small	do	22
lo		3.00	do	Dom	41
	97.00	3.50	Good	Dom; st	37
e			do	do	33
d		4.00	do	Dom	16
do		3.00	do	Dom; st	12
do			do	do	13
do		4.00	do	do	8
nd			do	do	9
d			Small	do	13

ternate layers.

[a] On high ground; 4 feet above average.

Wells in Kings River delta—

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strat
							Feet.	*Feet.*	*Feet*	
728	Mr. Stewart	19	21	3	1900	B5	24	8	16	SHp
729	Ben Scribner	19	21	4		B5	70	10	60	
730	W. W. Robinson	18	21	31	1888	B6	42	10	32	SC
731	Camp estate	19	20	1	1885	B		10		
732	Mrs. H. F. Bryant	18	20	35	1890	B6	60	8	52	
733	Mrs. Hunkey	18	20	34		B5		8		
734	Ger. S. and L. Bank	18	20	34	1891	B7	240		240	SC
735	W. H. Crowder	19	20	10	1900	B5	34	8	26	LCS
736	E. W. Clithero	19	20	14	1890	B5	60	6	54	CS
737	W. D. Runyon	19	20	12	1896	B5	122	7	115	CS
738	O. D. Brown	19	20	1	1893	B5	40	4	36	CS[a]
739	M. Kerchert	19	21	7	1890	Dr1½		8		
740	R. P. Gray	19	21	18	1882	B6	20	7	13	LSC
741	Mrs. D. Copeland	19	21	17	1885	B5	35	7	28	
742	C. Manter	19	21	8	1879		50	8	42	G at bott
743	S. J. White	19	21	5	1880	B5		7		
744	Chas. Feahill	19	21	9	1890	B5	46	8	38	SC
745	J. L. Walker	19	21	8	1897	B5	66	9	57	S
746	Geo. Rich	19	21	9	1889	B5	30	7	23	SC
747	R. Burton	19	21	32	1893	B5	28	12	16	SC
748	Marriott & Mathus	19	21	30	1898	B5	104	12	92	SC
749	Mrs. S. Wilson	19	21	28		B5		10		
750	Mr. Dunner	18	22	31	1888	B5	28	10	18	SC
751	J. O. Hickman	18	21	25	1890	B5	24	7	17	LS
752	J. C. Rice	18	22	18	1888	B5	54	6	48	CS
753	L. N. Gregory	18	21	13	1888	B5	82	7	75	CS
754	People's Ditch Co	18	21	1	1897	B5	46	7	39	CS
755	A. J. Cortner	18	21	1	1891	B5	38	12	26	CS
756	Boston Raisin Co.	18	21	3	1896	B5	52	10	42	
757	C. J. McCullah	17	21	35	1890	B5	52	7	45	LS
758	Mrs. Sutherland	17	21	26	1893	B5	35	10	25	SC
759	P. C. Phillips	17	21	27		B8		10		CS
760	do	17	21	28	1899	B5	48	13½	34½	SC
761	Love & Chittenden	17	21	33	1900	B		8		
762	Timothy Page	18	21	4	1890	B5		8		
763	do	17	21	32		B5	30	8	22	
764	C. H. Smith	17	21	32	1897	B5	30	10	20	S
765	Timothy Page	17	21	31		Dr2		10		
766	Crocker estate	18	21	6		B5		10		
767		18	21	8		B5		10		
768	R. V. Daggett	18	21	4	1880	B6	40	10	30	
769	J. W. Lane	18	21	22		B5	61	9	52	
770	Banner Vineyard	18	21	14		B5		8		
771	Hanford Co. Nat. Bk	18	21	23		B5		8		
772	Wetmore Bros	18	22	29	1885	B7	35	8	27	CS
773	J. M. Fox	18	22	28		B5		8		
774	F. G. Ferreiro	18	22	22		B5	35	6		
775	Alex. Taylor	18	22	22	1894	B5	40	7	33	S
776	Willow Grove schoolhouse.	18	22	24		B5		8		
777[b]	E. Y. Bock	18	22	24	1878	B4	70	12	58	CS
778	M. D. Fierra	18	22	13		B5		9		
779	S. S. Cerderberg	18	22	11	1886	B5	54	8	46	SC
780	David Burris	18	22	12	1900	B5	58	8	50	CSHp
781	Sacramento Bank	18	22	11	1900	B5	32	9	23	
782	Pike Clough	17	23	30	1896	B5	40	10	30	LCS
783	Chas. Barlow	17	23	30	1885	B6	40	8	32	SC
784	E. Jacobs	17	22	25	1885	B8	60	9	51	CS
785	S. Sweet	17	22	25	1884	B5	35	8	27	
786	Silas Simons	17	22	24		B5		9		
787	David Burris	17	22	22	1900	B5	53	9	4	CS
788	do	17	22	27	1886	B5	40	12	28	S
789	J. W. Dawson	17	22	35		B5		8		
790	Excelsior schoolhouse.	17	22	34		B5		8		
791	J. R. High	18	22	20	1897	B5	25	6	19	
792	H. Marshall	18	22	17	1900	B5	92	7	85	
793	Eureka School	18	22	22	1893	B4		7		
794	R. W. Morgan	18	22	15	1888	B5	60	9	51	
795	S. A. Thompson	18	22	10	1889	B5	66	8	58	CS
796[b]	Mrs. J. M. Clark	18	22	3	1890	B5	62	12	50	CS
797	W. F. Farmer	18	22	9		B5		8		
798	E. Jacobs	17	22	33	1885	B6	44	8	36	CS
799	Cosmos L. and W. Co.	17	22	33	1874	B6	65	8	57	SCG

[a] Alternate layers.

Kings counties—Continued.

Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
and		$24.00	Good	Dom; st	9
do		4.00	do	Dom	8
do	$21.00	3.50	do	do	12
do		4.00	do	do	11
orse	60.00	6.00	do	Dom; st	11
and		4.00	do	do	
do			do	do	19
	16.00		do	do	19
and		6.00	do	do	29
do	61.00	3.50	do	do	18
do		3.00	do	do	10
do		3.50	do	Dom	11
do	12.00	3.00	do	Dom; st	12
do		3.00	Small	Dom	12
do		3.00	Good	Dom; st	12
Vind			do	do	11
and	23.50	3.50	do	Dom	12
do	33.00	4.00	do	Dom; st	12
do		4.00	do	do	13
do	14.00	3.50	do	do	18
do	54.00	3.50	do	do	35
do		3.00	do	do	14
do	14.00	3.00	do	do	10
do	18.00	4.00	do	do	11
wind	48.00	38.00	do	do	11
and	41.00	4.00	do	Dom	18
do	23.00	3.50	do	do	10
do	28.00	3.00	do	do	10
do	26.00	3.50	do	Dom; st	8
do	36.00	3.50	do	Stock	11
do	18.00	3.50	do	Dom; st	8
do		6.00	do	Dom	9
do		6.00	do	do	8
Vind		4.00	do	Stock	9
and		4.00	do	Dom; st	10
do			do	do	9
do		4.50	do	do	10
team			do	do	8
and		3.50	do	do	11
do		2.75	do	Stock	10
do		2.75	do	Dom; st	19
wind	31.00	30.00	do	Dom	8
Vind; hand			do	Dom; st	10
and		3.50	do	Dom	8
Vind; hand	27.00		Small	Dom; st	29
do		3.50	Good	do	14
and		4.00	do	Dom	22
do	20.00	4.00	do	Dom; st	40
do		3.00	do	Dom	34
do		350.00	do	Dom; st	150
do		3.00	do	do	141
do	39.00	3.50	Small	do	14
do	37.50	6.00	Good	do	30
do	20.00	3.50	do	do	14
do	30.00	3.00	do	Dom	16
do	40.00	3.50	do	do	12
Vind	45.00	6.00	do	Dom; st	12
and		3.50	Small	Dom	14
do		5.00	Good	Dom; st	14
do	33.00	5.00	do	do	8
Vind; hand			do	Dom	12
and		3.50	do	do	
do			do	do	13
do	13.00		do	do	24
do			do	Dom; st	12
do		3.00	do	Dom	10
do		5.00	do	Dom; st	12
			do	Dom	21
wind	30.00		do	Dom; st	11
and		3.50	do	do	12
do	33.00	6.00	do	do	14
do	65.00	6.00	do	do	8

[b] On higher ground.

Wells in Kings River delta—Fresno,

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well. Feet.	Depth to water. Feet.	Depth of water. Feet.	Strata.
800[a]	Montgomery Bros	17	22	34	1900	B5	56	13	43	SCG
801	Mr. Jenkins	18	21	4		B5	30	8	22	
802	William A. French	17	21	32	1888	B6	35	8	27	SC
803	M. E. Templeton	18	21	5		B5		8		
804	M. B. V. Garcia	17	22	29	1899	B5		8		
805	Mr. Van Dorset	17	22	29	1900	B5	44	8	36	SC
806	C. W. Clark	17	21	36	1885	B5	60	11	49	SC
807	T. J. Alcorn	17	21	25	1900	B5	42	11	31	SC
808	R. H. G——	18	23	5		B5		9		
809	Frank Griffith	18	21	29	1894	B5	38	12	26	SC
810	Joe Rogers	18	21	28		B5		11		
811	S. B. Hicks	18	22	33	1880	B5		9		
812	Perry C. Phillips	18	22	35		B5		9		
813	....do	18	22	25	1900	B5	138	12	126	SC
814	....do	18	22	36		B5		16		
815	J. H. Murray	19	21	12	1892	B5	43	14	29	CS
816	W. Hampshire	19	21	11	1900	B5	30	8	22	LQsCS
817	R. Abbot	19	23	3	1899	B4	100	9	91	CS
818	P. Sweeney	19	23	14	1878	B5	40	8	32	SCSC
819[a]	Mrs. M. J. Covert	19	21	32	1878	B5	40	14	26	S
820	G. L. Fletcher	19	22	15	1889	B5	56	10	46	
821	Cal. S. and L. Soc	19	23	9	1880	B4	+22	10	+12	
822	Harry Peacock	19	23	3	1873	B5	75	9	66	
823	E. Pichett	18	23	35	1885	B5		9		
824	F. M. Hart	19	23	4		B5		9		
825	Cross Creek schoolhouse.	18	23	32		B5		9		
826	C. Waldorf	19	23	5		B4		8		
827	Fred Dunn	19	23	7		B5		12		
828	M. Braverman	19	23	9		B5		9		
829	Evelyn Davis	19	23	17		B5		9		
830	Robt. Dougherty	19	23	21		B5	15	8	?	
831	Eucalyptus schoolhouse.	19	23	21		B2		8		
832	S. L. Worley	19	22	28	1880	B5	30	13	17	
833	Robt. Dougherty	19	22	23		B5	30	14	16	SC
834	T. McCarthy	19	22	34	1876	B5	75	13	62	
835	Mrs. J. T. Hereford	19	22	34	1875	B6	40	11	29	
836	H. M. Richardson	19	23	34	1875	B5	30	10	20	
837	E. McCarthy	20	23	3		B5	64	14	50	
838	Wm. Rourke	20	22	3	1888	B5	30	17	13	SC
839	W. H. Heldebrand	20	22	10	1880	B5	34	16	18	
840	J. M. Moore	20	22	10	1900	B7		15		
841	Lakeside School	20	22	5		B5		14		
842	P. McCarthy	20	23	8	1886	B9	600	(b)		CS
843	F. E. Howe	20	23	8	1891	B8	750	(b)		
844	Lakeside Creamery Co.	19	22	33	1890	B5	60	15	45	SC
845	Geo. Clute	19	23	31	1885	B10	900	(b)		CS
846	J. H. Deardoeff	19	23	8		B5		10		
847	Susan Hill	19	23	20	1899	B5	30	10	20	
848	S. A. Brewer	19	23	20	1891	B5	54	12	42	SC
849	Sacramento Bank	19	23	29		B5		12		
850	A. & J. Toomey	19	23	32		B6		(b)		
851	Wm. Northup	19	22	31	1898	B5	30	12	18	CS
852	Mrs. C. Brown	18	22	15	1880	B5		12		
853	C. A. Roberts	18	22	16	1891	Drl		8		
854	E. Jacobs	18	22	17		B5		11		

[a] On higher ground.

[b] Flows.

d Kings counties—Continued.

Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Hand	$28.00	$3.50	Good	Dom	10
do		3.00	do	Dom; st	8
do	17.00	3.50	do	do	13
8 wind		50.00	do	do	11
12 wind; hand			do	do	9
Hand	22.00	4.00	do	Dom	8
do	60.00	4.00	do	do	10
do	14.00	5.00	do	Dom; st	11
do			do	do	52
do	27.00		do	Dom	13
do		3.00	do	do	21
do		2.25	do	do	12
do		5.00	do	Dom; st	31
do			Small	Dom	50
do		4.00	Good	do	16
do	40.00	3.25	do	Dom; st	11
do	22.00	3.25	do	Dom	8
do	50.00	3.00	do	Dom; st	39
do	40.00	2.25	do	do	10
Hand; wind		3.25	do	do	10
Hand	56.00		Small	do	12
do		5.00	Good	do	48
14 wind; hand			do	Dom	16
Hand		3.00	do	Dom; st	28
8 wind		3.50	do	do	8
Hand		3.50	do	do	12
do		6.00	do	do	20
do		3.50	do	do	16
do			do	do	46
8 wind		41.00	do	do	128
Hand		5.00	Small	do	226
do		2.25	Good	Dom	9
do		3.50	do	Dom; st	18
			do	do	14
Hand		3.50	do	do	12
do	40.00	6.00	do	Dom	8
do		20.00	do	Dom; st	14
do	64.00	2.75	do	do	17
do	30.00	4.75	do	do	9
8 wind	34.00	114.00	do	do	12
do		50.00	do	Stock	
Hand		3.50	do	Dom	11
	1,500.00			Dom; st; irr	13
	1,250.00			do	12
Hand	45.00	12.00	Good	Dom	15
Artesian	1,900.00			Dom; st; irr	15
Hand		2.25	Good	Dom	27
8 wind		35.00	do	Stock	17
Hand	30.00	2.50	do	Dom; st	20
14 wind; hand			do	do	18
				Stock	13
Hand	22.00	3.00	Good	Dom; st	19
do		3.00	do	do	12
do			do	Dom	11
do		3.00	do	Dom; st	11

In 1882 Mr. C. E. Grunsky, then an assistant in the California State engineering department, made a careful study of the Kings River water supply. In 1898 he made a further study of the district for the hydrographic division of the United States Geological Survey, the results of which are published as Water-Supply and Irrigation Paper No. 18, which has previously been referred to and from which the following extracts regarding the ground water are made:

In no other irrigated region in California is the effect of irrigation on the elevation of the water table so plainly apparent as in the vicinity of Fresno. Here, notwithstanding the 6 feet per mile slope of the surface of the country, the subsoils have been and are being gradually saturated with water. When irrigation commenced the loss of water from canals in transit to lands to be irrigated was very great, and after reaching its destination it was found that frequently enough water was put upon the surface of individual small tracts of land to have covered them to an average depth of 15 to 20 feet in a season. Most of this water found its way into subsoils, together with the direct loss of water from the canals. When the first wells were dug at Centerville water was found at about 20 feet. It is now at 10 to 15 feet below the surface, and will probably not rise much higher on account of ample drainage of subsoils and a comparatively free subsurface flow toward the low river bottoms. [The same in 1900.]

Along Fancher Creek, where the creek is used as a canal, ground water was formerly at 50 to 75 feet below the surface; it is now at 12 to 20 feet along the upper portion of the creek, and still nearer the surface near the former sink of the creek, about 4 miles east of Fresno. In the Eisen vineyard, 5 miles east of Fresno, ground water is at 4 to 6 feet below the surface, and drain ditches have been constructed to prevent a further rise. Ground water is found at 4 feet below the surface in many parts of Temperance Colony, Nevada Colony, and Fresno and Central colonies. Throughout a considerable area near Fresno its surface is nowhere more than 16 feet below ground, though before irrigation commenced depth to water was 60 feet. Cellars which were in use until 1884 in Fresno have been condemned because ground water made its appearance in them. Near Selma and Kingsburg ground water was formerly found at about 30 feet. It is now at about 15 feet. [It was at 12 feet in 1900.] The so-called "Sand Hollow," which is a depression 100 yards to one-fourth of a mile wide, 12 miles long, and about 16 feet deep, having a southerly course, and passing about midway between Selma and Kingsburg, was formerly as dry as the surrounding plain. About 1880 the soil in its bed was found to require less moisture to produce crops than the adjacent plain; in 1885 water appeared at the lowest points of the bed, and in June of that year it had risen to the heads of ripening grain. Spots of black alkali now mar its bed and sides, which before were a light sand, apparently free from any excess of alkaline salts.

Near Sanders and at points eastward from there toward Kings River ground water was at 50 to 60 feet before irrigation commenced: it is now at 20 to 30 feet. Here, as in the case of Centerville, proximity to the river, which lies 60 feet below the surface of the plain, may interfere with a much greater rise of the ground-water plane.

In connection with this change in the elevation of the ground-water plane, it must be remembered that the effect of irrigation extends far beyond the points now under ditch. Owing to the slope of its surface and consequent hydrostatic pressure, ground water has a slow but certain motion westward through pervious subsoils of the Fresno region, and may therefore ultimately contribute more or less toward the flow of Fresno Slough and San Joaquin River.

At the time irrigation commenced near Fresno the soils and subsoils were dry; depth to ground water was 30 to 60 feet. The ground was porous, generally sandy, *sometimes very hard* on the surface. When wet it was converted into a bog-

Water passed through it readily into the lower strata. Thorough wetting compacted the soil and it was less liable to conversion into slush after the first and second wettings than before. It settled, as a result of the first wetting, about 8 inches to 1 foot, on an average. Sometimes the full supply of a ditch would flow for hours into a hole formed by the breaking in of the surface. Cavities 20 feet in diameter and 6 to 10 feet deep were occasionally formed in this way, and had to be refilled after the first wetting. The stability of buildings was in danger when water was first brought near them. It is not surprising, under these circumstances, that when irrigation commenced in this region sometimes enough water was run on small areas at one irrigation to have covered them 5 feet in depth, and that enough water was delivered to some of the 20-acre colony lots south of Fresno to have covered them to an average depth of 20 feet. After irrigation was practiced for a time the soils became more compact, absorbed water less rapidly, and a smaller amount of water passed into subsoils. At present the ground water near Fresno is so near the surface that the roots of alfalfa, vines, and trees readily penetrate to it and soils are kept moist by the water rising from below. Surface wetting has become unnecessary in many sections.

By the rising of the ground water plane near Fresno large tracts of land have been permanently moistened. Some are very thoroughly subirrigated, and in many instances injuriously so. Relief must be sought in some localities either by drainage or by proper regulation of the supply of water to the district whereby the elevation of the water table may be controlled.

Without attempting to express in detail the acreage irrigated per cubic foot per second of canal capacity or actual flow of water, it may be noted that the total volume of water brought to the vicinity of Fresno during the seventeen years 1879 to 1896 would at a very low estimate have covered to an average depth of about 0.8 foot per annum the entire 260,000 acres of the region through which the canals send their branches. It would have covered the 50,000 acres to whose surface water is actually applied to an average depth of 4½ feet per annum, or to a total depth of 75 feet. Some of this water has of course been consumed in sustaining plant life, more has been evaporated, but the most of it still permeates the subsoils of the irrigated region and of the lands to the west.

Pl. XXVI shows the regimen of the water plane near Hanford as determined by Mr. Grunsky.

A study has been made of the amount of water that has been used for irrigation on the Kings River delta during the last five years. It has been assumed that 4,000 second-feet of water (the aggregate discharge of the canals), when available from the river, were diverted between March and October, inclusive, and that during the remaining four winter months 2,000 second-feet, when available from the river, were diverted for irrigation. From the tables of daily flow the following results were obtained, on the foregoing basis:

Estimated seasonal diversion for irrigation from and seasonal flow of Kings River.

Season November 1 to October 31.	Seasonal irrigation diversion.	Total flow.
	Acre-feet.	*Acre-feet.*
1895-96	1,070,900	1,852,425
1896-97	1,198,601	2,088,924
1897-98	820,522	876,079
1898-99	996,307	1,227,217
1899-1900	1,032,158	1,281,051
Five-year mean	1,023,716	1,465,139

Probably one-fourth of the amount diverted is lost by seepage f the main canals and their laterals. Prof. L. G. Carpenter, of Colorado Agricultural College, found that on Cache la Poudre R 30 per cent of the water that was applied for irrigation returned to river below by seepage. Still larger percentages have been fo in Utah, and the writer personally knows that similar conditions e on Gila and Salt rivers in Arizona. If one-third of the remain water applied on the fields for irrigation sinks to the water plane, have a total seepage volume from losses in transit and from irr tion of 511,858 acre-feet annually. This great volume of gro water undoubtedly has a slow westerly movement in harmony with surface slopes. This is indicated by the fact that there is a mar annual fluctuation in the elevation of the water plane, it being fi 2 to 4 feet higher about July 1, after the heavy spring irrigati than in October, at the end of the season's drought. If a pump system were put in to draw upon this water plane for irrigation p poses, a portion of the water pumped would be lost by evaporati but probably one-third would return to the water plane. Thu 300,000 acre-feet of water were pumped the permanent withdra would be not more than 200,000 acre-feet, and the annual sup would be from two to three times that amount.

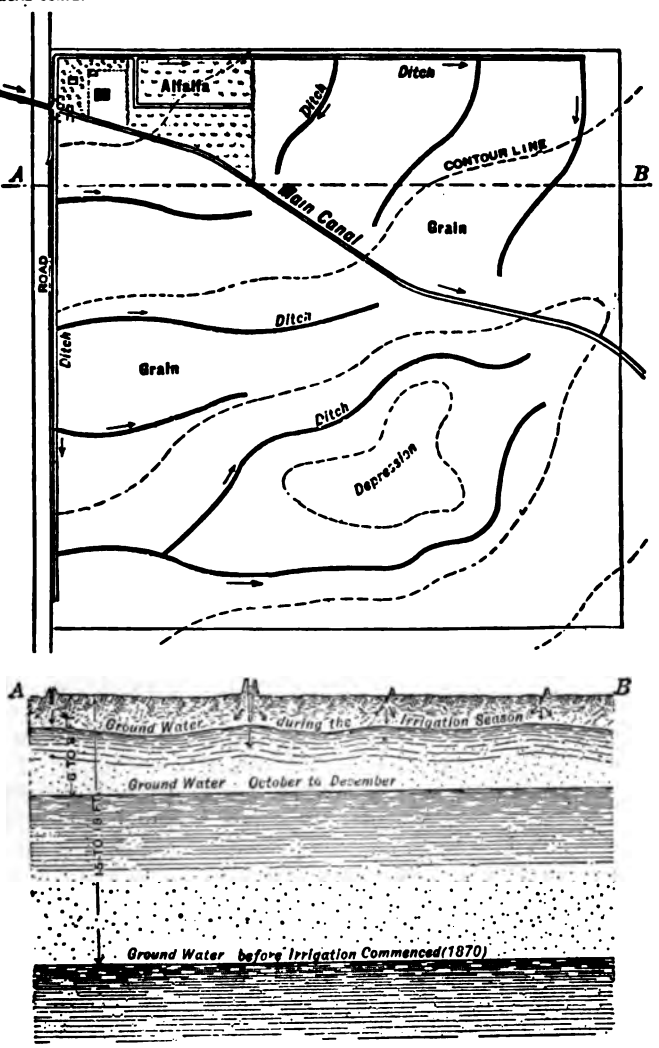
From the foregoing facts it is believed that a supply as grea 300,000 acre-feet can be obtained with certainty by pumping fi the water plane of the Kings River delta.

The annual replenishment of the ground water is briefly discus (pp. 87 to 88) in the accompanying report of Mr. Lewis A. Hicks the generation and transmission of electric power and the installat of pumping plants.

As there is a heavy loss in the diversion canals, as this loss incre with their length, and as the general movement of the ground w is with the slope of the country in a southwesterly direction, i believed that the best location for the pumping plants is near lower ends of the canal lines and at the westerly portion of the i gated lands. If located there a portion of the loss from the ca would be obviated, owing to their shorter length, and at the s time the pumping plants would have an ample water supply and lift for the pumps would be slightly less. If the pumping plants v located near the upper end or the center of the canal lines they w probably draw directly from the canals water which otherwise w flow to its destination by gravity.

ALKALINE CONDITIONS.

The water of Kings River is almost chemically pure. Its alkali is negligible. The alkali encountered in the valley comes from soil, largely from a calcareous hardpan which is found in some lo *ties. In rising the* water plane reaches the point where capillary ac



PLAN AND GEOLOGIC SECTION SHOWING EFFECT OF IRRIGATION ON WATER PLANE IN THE HANFORD AREA OF THE MUSSEL SLOUGH COUNTRY, CALIFORNIA.

tinually draws water from below and evaporating leaves practically all of the dissolved salt on the surface of the ground. Anything that will lower the water plane will tend to the reduction of surface alkali. If the voids in the soil be taken as one-third of the mass and 0,000 acre-feet of water are removed each year, then 600,000 acre-feet of soil are drained, equivalent to a depth of 2 feet over the entire irrigated area. It has previously been shown that this amount will be supplied from the river. Nevertheless the tendency of the pumping plants would be to prevent the water-logging of the land and its alkalinity. As the amount of pure river water that is added to the water plane each year is greater than the amount of water that would be pumped and partially evaporated, the tendency would be to continually dilute the salt in the ground water. It is believed that the alkali is caused by the rising water plane, and it is likely that one of the principal provinces of the pump in the future will be to fight alkali by keeping down the water plane.

Mr. Thomas Means, of the Division of Soils of the United States Department of Agriculture, has personally made a study of alkaline conditions of the soil and water of the Kings River delta. He has devoted a great deal of time and thought to the general study of the alkali problem, and his views are very valuable in considering this subject. He has kindly furnished the following for use in this report:

The salt content of the waters near Fresno has been plotted. No marked lines of zones of underflow were found. The wells with the greatest amount of solids seem, however, to be in the alkali area and along the lower part of the valley. The wells in the portion of the valley north of Fresno are generally of lower salt content than the wells south of Fresno, yet an occasional well with a salt content as high as from 15 to 20 parts is found.

The water table under the Fresno Plains before irrigation was commenced averaged from 30 to 120 feet below the surface. At present the average depth to standing water in the Fresno area is about 10 feet, and during part of the year the level rises about 3 feet. Much of the area south and east from Fresno has the water table at about 6 feet, and during part of the year this level rises to within 2 or 3 feet of the surface. The Hanford area of Mussel Slough country has the level of standing water about 8 feet below the surface of the ground. [See Pl. XXVI.] During the winter the level of this standing water rises about 4 to 6 feet, so that over a great deal of the country the water table is within from 2 to 4 feet of the surface. Here the salt content of the water is greater than around Fresno, averaging about 20 parts per 100,000, while a few wells contain over 100 parts per 100,000.

The salt content of the water of Kings River is about 8 parts per 100,000, the most of which is lime carbonate. The scheme proposed for the irrigation of the desert lands of the area with the water pumped from below the land seems perfectly feasible to me and should, from the way I reason, lessen instead of increase the trouble with alkali. There is but one source of addition of alkali to the country, that is, the water which is taken out of Kings River for irrigation. This water is so pure and the salts which it does contain being lime salts are a benefit rather than a detriment to plant growth. For all practical purposes the only alkali with which we have to deal is the alkali which is at present in the soil.

Alkali salts to be harmful to vegetation must be concentrated within the top 2 feet of soil. Buried below this depth, or if evenly distributed through the soil in

quantities not greater than 0.4 per cent of the dry weight of the soil, no trouble is ever experienced in raising ordinary farm crops (except in the case of the carbonate of soda or black alkali, which is harmful if present in quantities greater than 0.1 per cent). If the alkali be allowed to accumulate near the surface of the ground the roots of the plants are unable to perform their proper functions and the plant suffers, fails to ripen the fruit or dies.

There is a difference in the rate of upward and downward movement of the alkali salts. Experience has shown that the alkali salts move upward more readily than the same salts can be carried downward. This is because the upward movements are entirely capillary and the film around the soil moves, while the downward movement is largely gravitational and through the larger pores so that the film movement is small. This explains the reason why it is that even after large quantities of water are applied to a field of alkali salts may yet come to the surface.

Since alkali rises mainly by virtue of the capillary movements of the soil moisture, the capillary powers of the soil and the depth to standing water are the controlling factors of the rise of alkali. By the capillary power is meant the rapidity with which the moisture will rise within the soil. A heavy clay soil will raise water by capillarity much higher than a sand or silt soil, but the rate with which the water is raised is so slow that the soil is said to be of low capillary powers. In the same way a sandy soil, although the capillary rise is rapid, the height to which the water rises is not great, and the soils are said to be of low capillary powers. Silt soils, soils composed of very fine sand, and loam soils with a medium percentage of clay are generally classed as soils of great capillary power. The alkali soils of the San Joaquin Valley are almost without exception soils of great capillary power. Other soils of the same area which had all the conditions necessary for the accumulation of the alkali salts at the surface, except the fact that the soils were of low capillary power, are to-day free from accumulation of alkali. The Fresno sandy loam, or white ash land as it is locally known, is of great and rapid capillary power. The greater part of the land has been injured by the alkali which it contained. On the other hand the Fresno white sand, which is found typically developed on the plains around Caruthers and which is of low capillary power, although it originally contained within 10 feet of the surface as much alkali as did the white ash land, is very seldom found troubled with alkali.

The second factor in the accumulation of alkali is the depth to standing water. So long as the level of water does not come closer than 4 or 5 feet from the surface of the ground, practically none of the soils will become alkaline if cultivated. The reason for the accumulation of the alkali in the colony lands south of Fresno is that during part of the year the level of standing water comes so close to the surface as to permit continual upward movement and therefore rapid accumulation of the salts. White ash lands around Selma are found very fertile and give large returns where cultivated in fruit, yet an examination of these lands has shown that they contain within 10 feet of the surface as much alkali as do some of the alkali soils south of Fresno. The difference is this: the level of standing water at Selma never comes close enough to the surface (never closer than 6 feet) to permit rapid upward movement of the water. The consequence is that the salts either remain in the deeper subsoil or are distributed throughout the 10 feet. If ever the level of standing water around Selma is allowed to raise to within 3 or 4 feet of the surface, large areas of now fertile land will be rendered barren.

In this respect the scheme proposed for pumping promises to be of great assistance in the prevention of the further extension of the area of alkali land, but it promises also to be of great assistance in the reclamation of the lands already damaged. The pumps will be most active at the time the water table is ordinarily highest, and the amount of water taken from the soil will probably either *prevent this rise or lessen its* height. There is no question that if this annual rise of

e water table could be prevented and the level of the water kept at its lower
dition the reclamation of all but the lowest of the alkali lands would be possible
ithout a great and expensive system of drains.

Now the question is: Would the continued use of the water which lies below the
nd so concentrate the salt that it would in time contain too much salt for plant
owth? My opinion is that it would not. You would be continually drawing
e water from the depth of say 50 feet and applying the water to the surface of
e ground. Part of this water would be evaporated, part used by the plant, and
rt would drain away to the rivers. The remainder would remain in the ground,
ut it would be continually diluted with the water which escapes from the irriga-
on canals and from irrigation and which now causes the annual rise of the water
ble. The absolute amount of alkali would diminish instead of increase, for the
lants would take up some of the salts and another part would drain away into
he country drainage. The concentration of the water would probably increase,
ut, as I have said before, I think the dilution of the irrigation water taken from
he river would prevent this. If the water is drawn from a depth of 50 feet there
re 15 feet in depth of water to be pumped before the same water is used the second
ime. Under ordinary pumping irrigation ten years would be required to effect
his, and during these ten years sufficient water would have filtered in from the
ravity irrigation around and above to dilute this salt. Moreover, at seasons of
ery high flood the soils could be irrigated with flood water at a slight expense,
ince the greater part of the country has been ditched.

Most of this applies directly to the Fresno country. Around Hanford the conditions would be slightly different, for here the rise in water table takes place in the winter; yet I can not see where this will affect the problem.

To sum the matter up, I think the result of pumping, if the pumping be carried on only to such an extent as to move the water which is now lost by seepage, would be to improve the conditions rather than to increase the trouble from alkali. The water table would be lowered sufficiently to permit the washing down of the alkali salts, and the salts, instead of being confined to the surface layers of the soil, would gradually be distributed throughout the 50 feet of soil, and by this dilution rendered harmless. The lowering of the water table would be of the greatest assistance to the reclamation of the lands already alkaline, and would probably permit this reclamation without extensive under-drains.

GENERATION AND TRANSMISSION OF ELECTRIC POWER AND INSTALLATION OF PUMPING PLANTS.[a]

INTRODUCTION.

The generation of power from the waterfalls of the high sierras flanking the wide expanse of unused yet fertile lands which form so large a part of the broad San Joaquin Valley, and its utilization, through electric transmission, for pumping the irrigating water supply in the valley, is a subject which fascinates the physicist as an example, on a large scale, of the conservation of energy, and it does not lose in attractiveness when considered as an engineering possibility quite within the range of known experimental results and susceptible of exact statement as to the cost of developing and producing continuously a unit quantity of water.

Several years ago the writer pointed out that the high load factor (the ratio of the average to the maximum load) which could be realized in the operation of a power plant handling a purely pumping load would reduce the cost of pumping sufficiently to make this method of water development economically possible, and as the result of the present investigation it is apparent that the required investment per acre-foot produced compares favorably with the cheapest surface-catchment projects, and that the annual cost of operating would be less than by any other method of extending the water supply, provided it is deemed advisable to operate the plant continuously throughout six or more months of the year. The very complete physical data which are available from the surveys, stream measurements and photographs taken have made it possible to study the problem in detail. It falls naturally into three subdivisions: (1) The possibility of power development on Kings River depending on the fa and minimum run-off available within reasonable limits of condu length; (2) the cost of generation, transmission, and application of sufficient power to pump 1,000 acre-feet of water daily for the irrigation of lands between Fresno and Hanford; and (3) the possibility of developing that amount of water continuously from the gravel storag of the alluvial cone of Kings River.

POWER AVAILABLE.

The site selected for the power house is at the junction of the Sout and Middle forks of Kings River, at an altitude of 1,980 feet. Th diversion planned is from the Middle Fork, through 14,000 feet of continuous tunnel, with working adits at frequent intervals, delive ing a maximum flow of 180 second-feet at the penstock, which is 68 feet above the water wheels.

[a] Report of Lewis A. Hicks.

The watershed tributary to this diversion contains an area of 325 square miles and rises to an altitude of 14,000 feet. The least mean monthly run-off during the last five years, which were years of drought, occurred in September, 1898, when the Red Mountain gaging records indicate an available mean flowage at the Middle Fork diversion of 85 second-feet. Following is the mean monthly minimum flow during these five years:

Mean monthly minimum flow of the Middle Fork of Kings River.

September—	Second-feet.
1896	206
1897	138
1898	85
1899	90
1900	126

In each year the minimum month was September. During the rest of the year the available flow was never less than 100 cubic feet per second, a quantity sufficient to generate the full load output contemplated. The recurrence of extremely dry seasons at more frequent intervals than ten or fifteen years is not probable and does not properly constitute a limitation of the plant to be installed.

ANNUAL REPLENISHMENT OF GROUND WATER.

A study of the water supply available for pumping, which has been fully considered by Mr. Lippincott, shows it to be ample to furnish the maximum of 328,500 acre-feet required annually by the pumping plants, and the supply will probably be much in excess of the demand.

Experience in Kern County, on a scale relatively as great, shows that the water plane is maintained, notwithstanding continuous pumping, where the wells are in proximity to gravity canals, and that while the plane of saturation is lowered during seasons when the canals are deprived of water it soon regains its former level when the use of the canals is resumed.

A careful study has been made of the data acquired by the extensive observations of the existing water plane in the Kings River delta, as revealed by more than 800 wells, supplemented by information given by well borers familiar with the district. The average wells for irrigating purposes have a log similar to the following:

Representative log of wells in Kings River delta.

	Feet.
Soil	7
Hardpan or clay	2 to 8
Coarse sand	10 to 50
Heavy clay	30 to 60
Coarse sand	4 to 6

The first layer of sand is generally found to be alkaline and is cased out, dependence being placed on the second stratum of sand, from

which the supply is drawn through the open bottom of the casin Under pumping such wells at first discharge considerable sand, cres ing around the casing a cavity of such dimensions that the enteri velocity of the water is reduced to a point where its transporti power is lost. Where the clay roof is sufficiently thick to preve caving these cavities may become very large and the capacity of t wells be proportionately increased. A formation of this character therefore exceptionally favorable to the development of large quantiti of water.

The storage capacity of the area affected by the annual infiltrati above the level to which the water plane might be reduced by conti uous pumping is not less than 2,000,000 acre-feet.

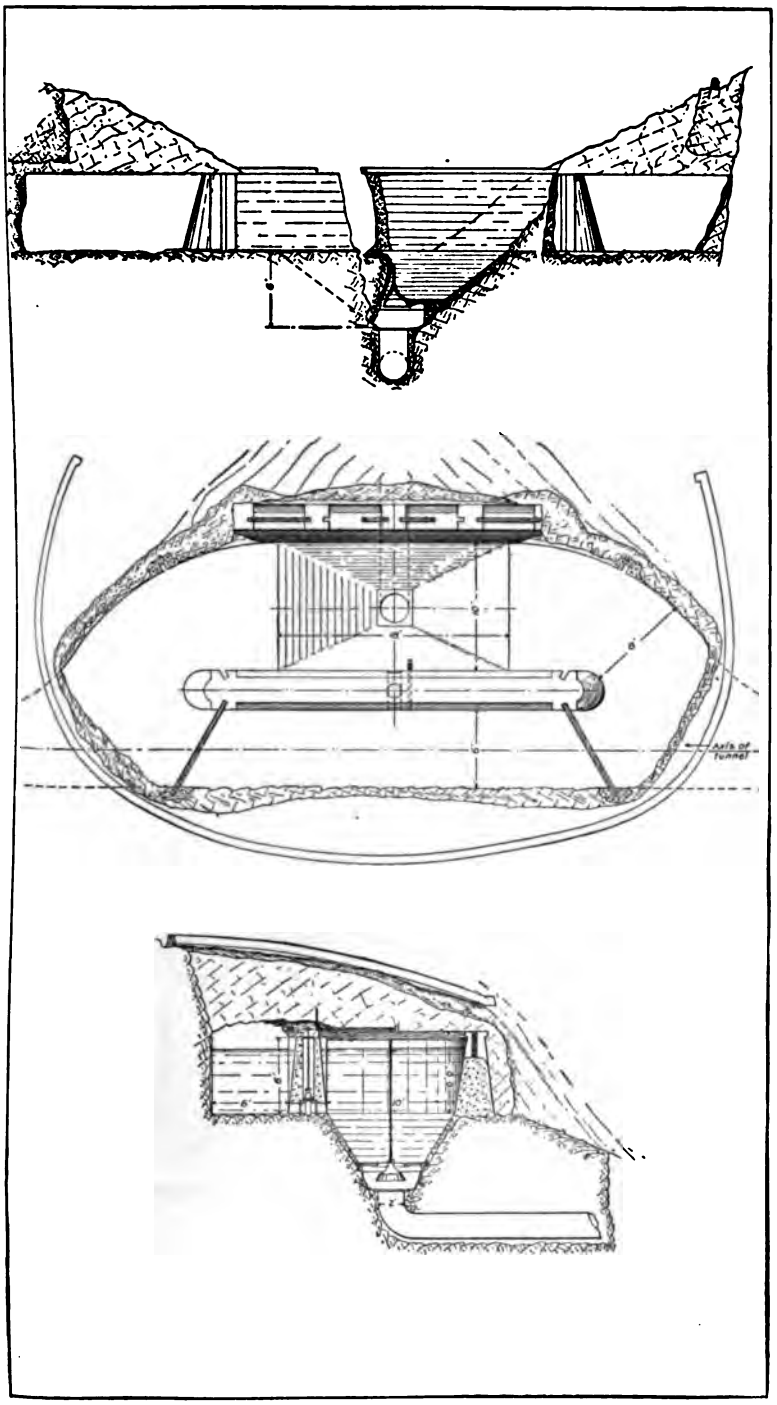
In the light of experience and of the data presented regardi storage capacity, rate of replenishment, favorable formations encou tered, and the reabsorption of a part of the water pumped, t writer believes it entirely conservative to say that the quantity water estimated upon in this report can be continuously develope from the gravel beds of the Kings River delta by the methods outline

PLANT PROPOSED.

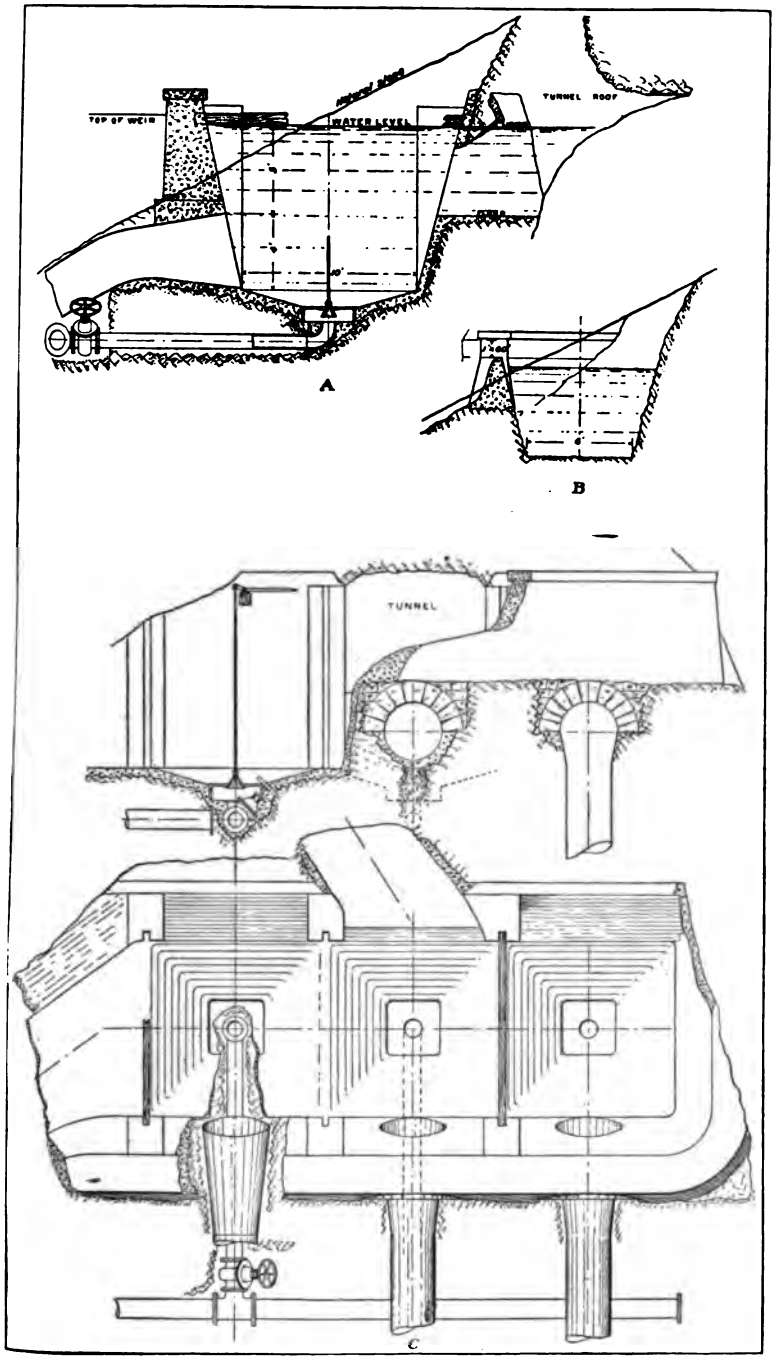
While the limits of this report make it necessary to omit many the details, the general characteristics of the designs will be state briefly before summarizing the estimates. The figures used for co of intake, conduit, roads, bridges, and trails were prepared from pr liminary surveys, and appear to the writer to be amply large to cov any probable modification of design or location. A description the rest of the plant follows in order, from the intake to the pump

SAND TRAPS.

Ordinarily the water is very clear and carries but little silt. Pr vision has been made, however, for trapping the granitic sand whic is present in all streams of the upper sierras during the spring fres ets, while the snow is melting. The saving effected in the erosion wheel buckets and nozzles justifies this expense. The normal condu velocity through the traps for full-load conditions has been reduce to a little more than 1 foot per second, and at the penstock th transverse velocity will be less than 0.5 foot per second. This has bee cheaply effected by locating the structure in one of the small later drainage lines intersected by the tunnel alignment at grade, an diverting the drainage around the open cut by means of a sma training wall. Movable flashboard will make it possible to flus the settling chamber withou interferi wit the continuous flow the conduit, and a by-pass wi equaliz the pressure on the flas boards. Flushing may be continuous when water is plentiful, an be intermittent or cease entirely when the flowage is less tha *required.* A waste weir is provided for regulation and for use whe



LONGITUDINAL SECTION, PLAN, AND TRANSVERSE SECTION OF SAND TRAP.



DETAILS OF PROPOSED POWER PLANT.

A, Section of tunnel; *B*, section of wasteway; *C*, plan of penstock.

t is desirable to shut off entirely the flow from the penstock. Pl. XXVII shows a longitudinal section, plan, and transverse section of the sand trap.

PENSTOCK.

As designed, this structure is divided into three bays, from each of which a pressure pipe is taken out. The bays can be separated by flashboards placed in grooves in vertical buttresses, and the pressure pipes can be shut off by stop boards between the buttresses. The tunnel enters the penstock in the center bay. The surface elevation of the water in the penstock can be regulated by stop boards between the portal buttresses. An overflow weir is provided to carry the maximum flow of the conduit when all outlets below are closed. Sections of the tunnel and wasteway and plan of the penstock are shown in Pl. XXVIII.

PRESSURE PIPES.

The three pipe lines are designed to be 30 inches in diameter, of steel plates riveted in place, with full-load velocities of 7 feet per second and an effective head of 660 feet, requiring a flow of 100 cubic feet per second to generate the rated output of the dynamos. Each pipe is equipped at frequent intervals with air valves of large area. The pipes are to be placed in a trench to a depth of half their diameter, anchored to rock in situ, and covered with rough rubble. A concrete thrust block is provided at the foot of each pipe, which tapers from a diameter of 30 inches at the thrust block to 18 inches at the gate valve (18-inch) in the power house immediately back of the nozzles. Each pipe feeds to a single generating unit, with practically no curvature in reaching the wheels. In case it is necessary, however, to feed two units from any one of the three pipe lines, this can be accomplished through a 30-inch by-pass connecting the three pipes back of the thrust blocks and not shown in the drawings.

POWER HOUSE.

In designing such a structure the endeavor should be to obtain, as cheaply as possible consistent with long life and utility, a safe and convenient assemblage of the necessary apparatus in such a manner that all working parts of the plant shall be easily accessible for repairs and that possible future extensions can be made in conformity to the same general plan, also to concentrate the machinery, so far as is consistent with safety, in order to minimize the expense of attendance. This has been the aim in planning these works.

The power house, as designed, is shown in plan, side elevation, end elevation, and transverse section in Pl. XXIX. It is believed that the intense summer heat justifies the substantial character of the design and that the use of the granite country rock will be cheaper than any alternative material offering results equally satis-

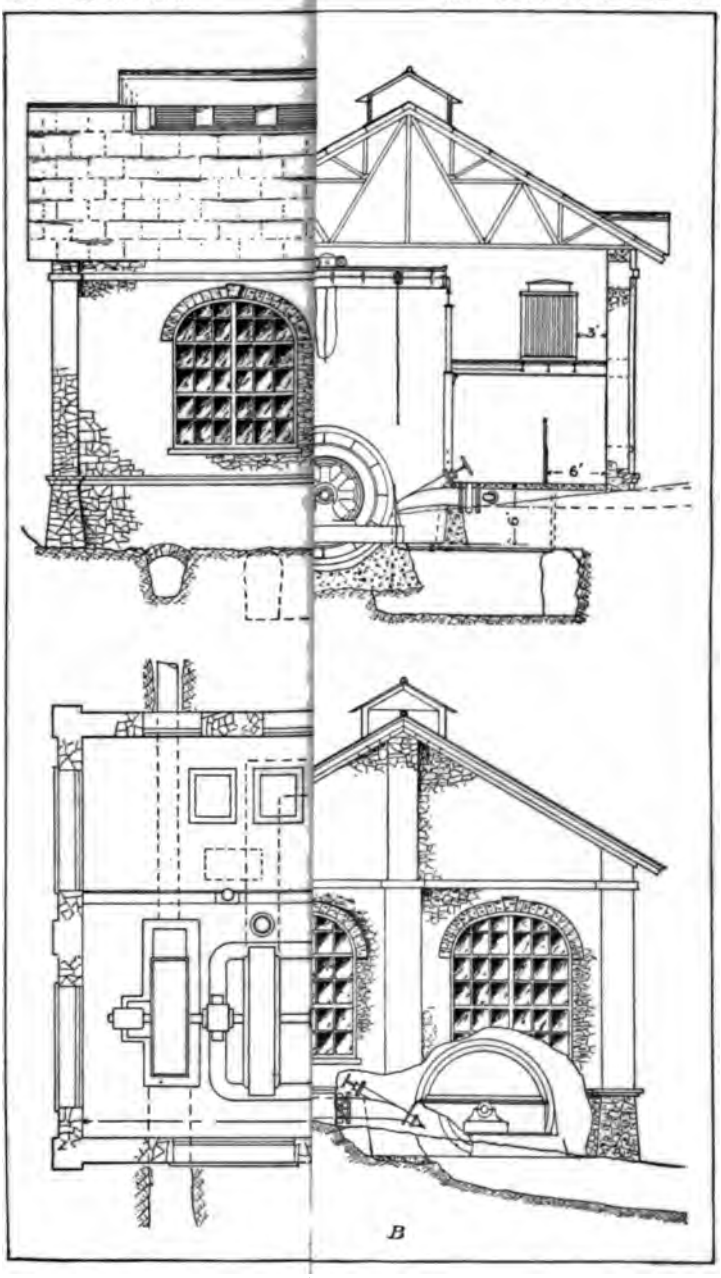
factory. Thorough ventilation will be obtained through louver openings in the roof ridge and by exhaust fans connected with the cool air in the wheel pits.

The pressure pipes and exciter branches are below the level of the switch-board floor, obviating the use of short goose necks on the main units. The tailraces provide a straight outlet for the waste water in direct line with the axis of the pressure pipes and offer head room for repair work under the wheel mounting. Work can be done on either unit without interference with the operation of the rest of the plant. Wire conduits for the leads from the generators to the low-tension busbars and exciter circuits are designed with ample working dimensions. The reasons for the arrangements adopted will be taken up in connection with the several classes of apparatus to which they appertain.

Hydraulic equipment.—As designed, the water-wheel centers are mounted on the shaft on which the revolving fields of the generators are carried, dispensing with an intermediate coupling, and are fitted with interchangeable single tangential buckets. The shaft is carried in three bearings of the usual ring-oiling type. The wheel housings part horizontally at the axis of the shaft, permitting easy access to the entire wheel. The nozzles are interchangeable, equipped with deflecting hood actuated by means of rocker shaft and links from a Lombard governor belted to the generator shaft. The nozzles are also provided with a needle valve for hand regulation if desired. The exciter units, two in number, are connected directly to their respective water wheels, either being of sufficient capacity to provide exciting current for two generators. The exciter tailwater will discharge into the main tailraces. The foundations for water wheels and generators to be excavated to solid rock, built up with concrete, and reenforced and tied together laterally with expanded metal and small I beams.

Generators.—The generators proposed, three in number, are of the 3-phase, 60-cycle, alternating-current, revolving-field type, with a normal capacity of 1,350 kilowatts, or 1,800 horsepower, at 2,200 volts, at a speed of 200 revolutions per minute, and are on the shaft with the water wheel. The stationary armature in this form of generator dispenses with any adjustment of moving parts on the generating element of the machine, as the leads simply connect to terminal blocks on the armature frame to which the ends of the 3-phase windings are brought. The elimination of collector rings, made possible in this way, tends to higher generating pressures, with resulting economy in transformers. Machines of this type of 12,000 volts capacity have already been developed and are in successful operation.

In designing these works moderate electric pressures have been adopted both for generation and transmission, with a view to keeping well within the limits of successful operation. As planned, the generating units are below the station floor, to permit the pressure pipe



B

o reach the wheels without unnecessary curvature, and plenty of working room has been provided around, under, and over the machines. A traveling crane provides means to lift and transport any part of the machines to any part of the building. The generator leads pass up from the subterranean working conduit behind the switch board to the busbars, where they are distributed to the transformers overhead. Wide passageways are provided around the switch board, which consists of a separate panel for each generator and one for the exciters, carrying the usual interconnecting switches, voltameters, ammeters, integrating wattmeters, fuse blocks, field rheostat, and synchronizing devices.

Transformers.—The floor or shelf on which the transformers are placed is of concrete and expanded metal, with working room between and around the transformers. The low-tension wires (2,200 volts potential) pass into the transformer coils on the rear, next to the wall of the building, and the high-tension wires (30,000 volts potential) are taken from the opposite side through a plug board equipped with long break switches, from which the wires pass back overhead, across the transformers, through glazed openings, to the external circuits.

POLE LINES.

The route selected for the pole lines follows in a general way the proposed wagon road from the power house to Millwood, and thence along the existing wagon roads to Centerville, in the valley below, for the purpose of insuring access to the lines during the winter, when the ground will be covered with snow. Beginning at an elevation of 2,000 feet the line attains an altitude of 5,500 feet at Millwood, and then descends to Centerville, 45 miles from the power house. Experience in Colorado and British Columbia demonstrates that if the lines are structurally strong no interruption of operation need occur by reason of snow. Interruption has invariably been due to weak mechanical construction and not to electrical causes. Two pole lines carrying four 3-phase circuits of No. 3 hard-drawn copper wire supported on suitable insulators to be built to Centerville, where a switch station will be located. The arrangement is such that each generator can be run separately on an independent circuit, or any number of circuits can be operated in multiple from a single generator, or all of the generators can be run parallel into any or all of the circuits by means of suitable connection at the busbars. From Centerville one line has been projected to Fresno and beyond and another to Hanford and the intervening lands.

SUBSTATIONS.

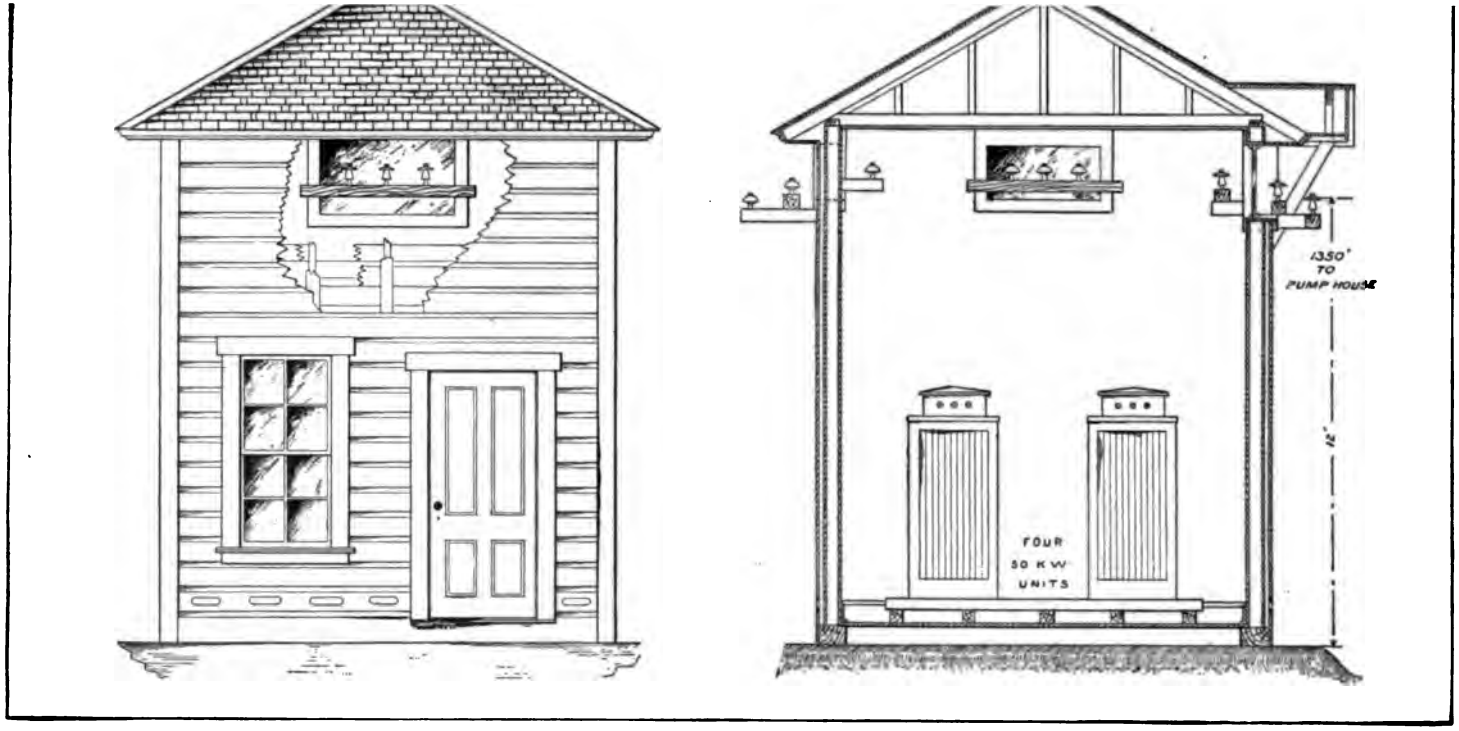
The extraordinary yield of the developed wells around Fresno, considered in conjunction with the depth to the plane of saturation, the probable depth of exhaustion of the wells, and the economical output for each station, *requires about* 45 horsepower delivered to the motors,

and the necessary size of the units suggests the use of 50-horsepower induction motors at 2,000 volts potential. The advantages of a large irrigating head have been obtained by grouping four pumping plants around a transformer station 800 to 1,200 feet distant. Each substation consists of a neat wooden building provided with a radiation wall so arranged that the heating of the air in the roof space creates a draft through the vent provided at the top, which establishes a circulation through the walls of the building and prevents the air within from attaining more than the normal temperature outside. The transformer house proposed is shown in elevation and section in Pl. XXX, and a section of its wall in Pl. XXXI, *B*.

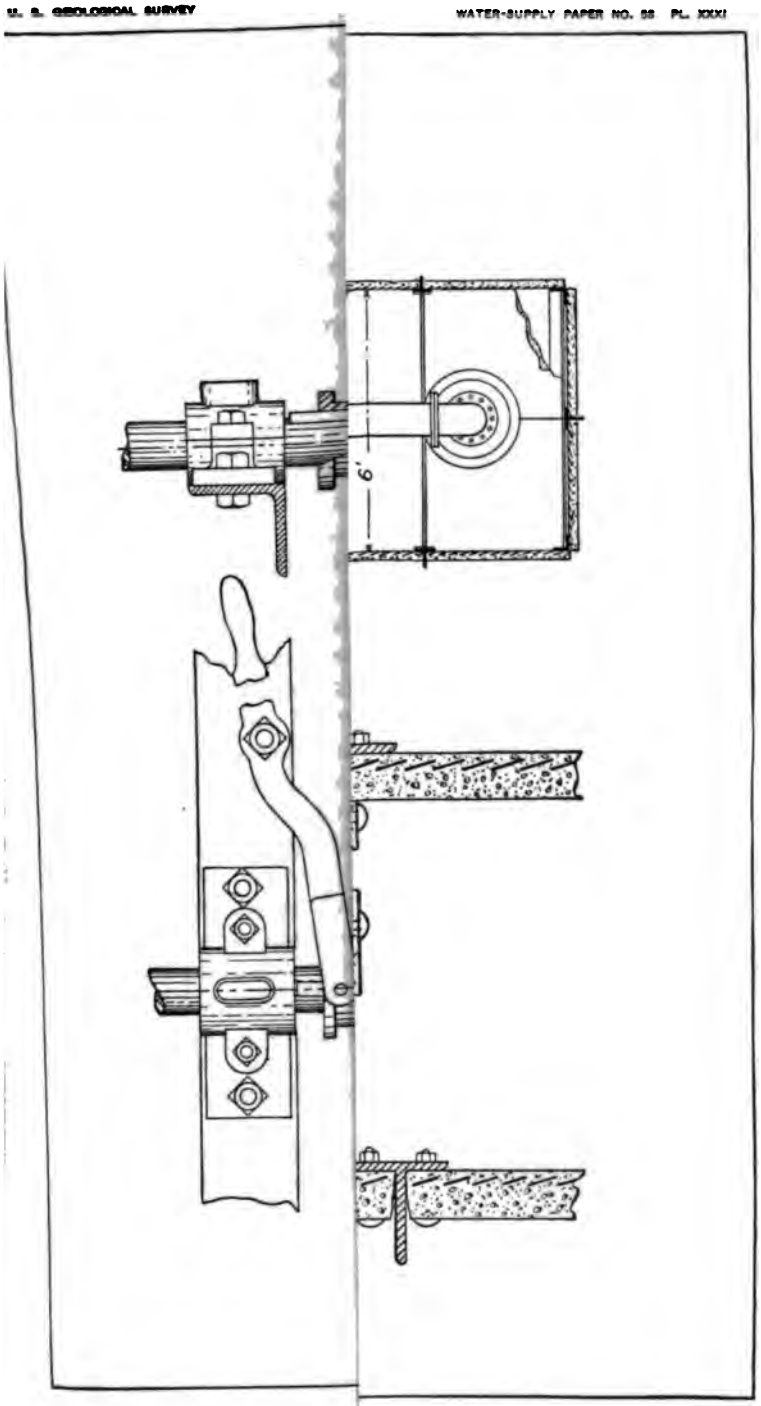
The equipment proposed consists of 200 kilowatts of self-cooling, oil-insulated transformers wound to convert the line pressure of 30,000 volts to a distribution potential of 2,000 volts, at which it is fed direct to the motors without further transformation. An outside high-potential, triple-pole, double, long-break switch provides means of cutting out the substations for adjustment.

PUMPING STATIONS.

These buildings are of the same general construction as the transformer house (For elevation and section of proposed pump house see Pl. XXXII.) As designed, the equipment consists of a 10-inch centrifugal pump, with working vanes to suit the motor speed and height of lift, mounted in a steel frame, connected directly, with grip couplings, to the shaft of a vertical motor supported on the same frame above the level of the surrounding country, so that in case the pit is accidentally flooded the electric apparatus is safe from injury and the plant suffers no damage. The pits are curbed with concrete and expanded metal panels set in steel T-beam frames and bolted in place, with diagonal bracing at the ends to prevent racking. (See Pl. XXXI, *D*.) The wells are 12 inches in diameter, sealed into the concrete floor, and will probably require sinking to an average depth of 100 feet. The suction pipes are 8 inches in diameter, of heavy galvanized iron, riveted and soldered. Suction inlet to the pumps is provided in the form of a cross, so that four wells, 90 degrees apart, can be connected. If the two wells shown in the section of the pit fail to develop sufficient water, another well will be sunk 30 or 40 feet away, laterally, and a fourth, on the opposite side, if it should prove necessary; these lateral wells to be connected by tunneling from the main pit, sinking a brick manhole over the well to the depth of the pit, and connecting the wall of the pit and the manhole by standard screw pipe surrounded by 6 inches of concrete, back-filled solidly and terminating at either end inside of the pits with a bolt flange from which connection can be made to the pump and vertical suction pipe. Priming is effected by closing the gate valve on the discharge pipe and exhausting the air from the suction pipes and pump with a mechanical primer operated with a taper friction from



ELEVATION AND SECTION OF PROPOSED TRANSFORMER HOUSE.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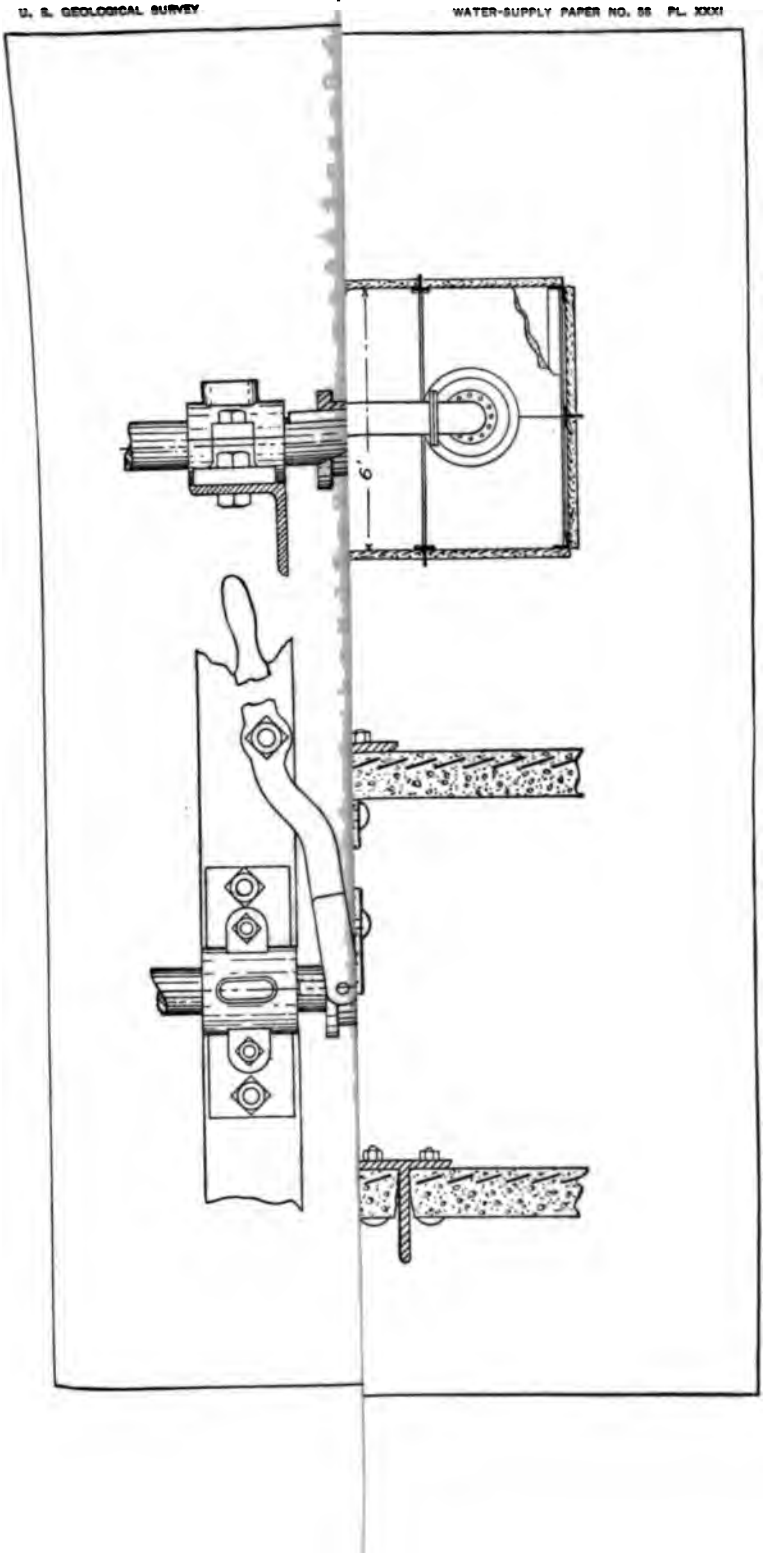
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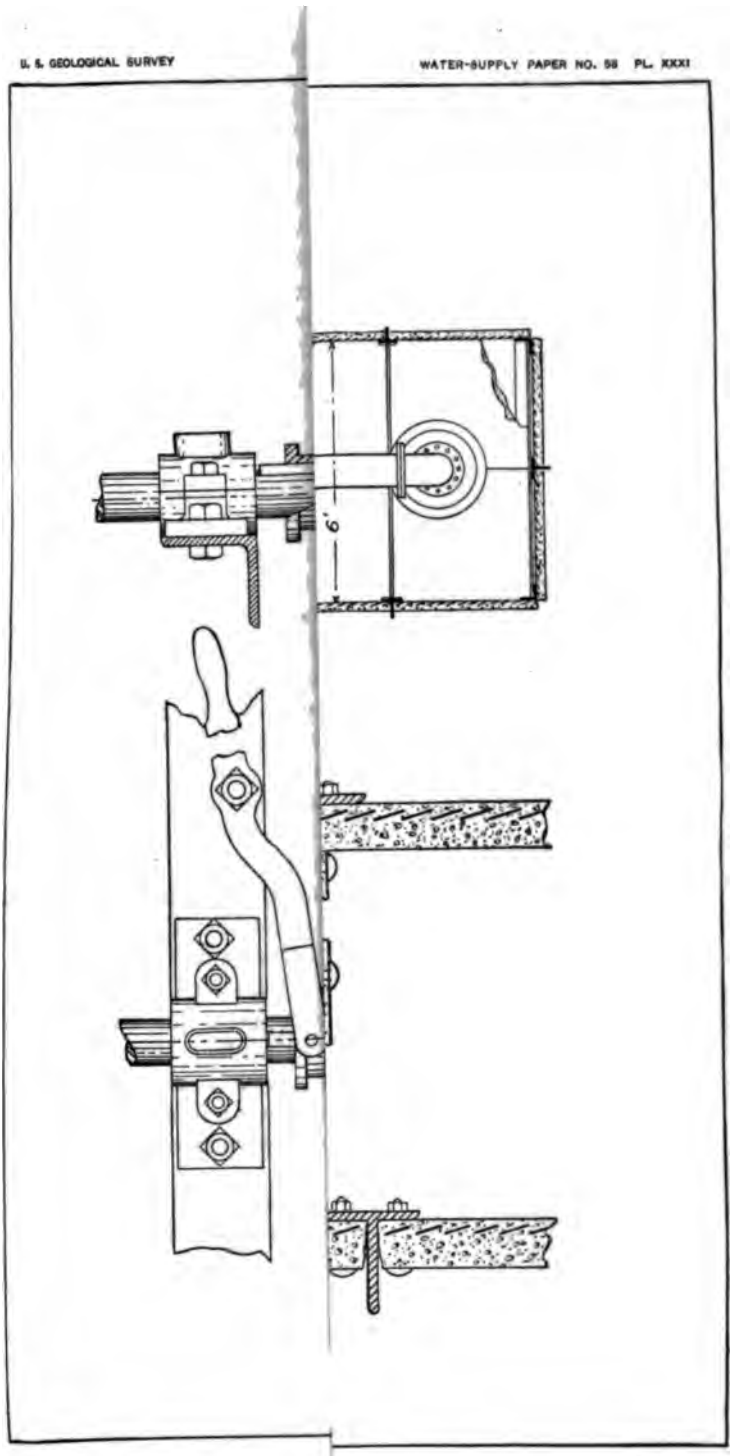
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he motor shaft. (See Pl. XXXI, *A*.) The motor starts idle, the weight of the motor and shaft being carried on a collar working on ball bearings on the pump head until the appearance of water at the discharge of the priming pump indicates the priming of the main pump. The opening of the gate valve on the discharge pipe permits discharge to begin, and the pump is so designed and adjusted that the static lift operates to balance the suspended parts. Each station is equipped with an automatic device for cutting out the motors in case of a disturbance of the line. Oilers are arranged to require attention once in twenty-four hours; more frequent inspection has been shown by experience to be unnecessary.

COST.

In the following estimate of cost wagon freight from Sanger to Millwood has been figured at $9 a ton, and from Millwood to the power house at $2 a ton. The figures used for the cost of the intake, conduit, roads, bridges, and trails were prepared from preliminary surveys, and appear to the writer to be ample to cover any probable modification of design or location. The delivery of construction material on the line of the tunnel and at the penstock requires the use of an inclined skidway and a small hoisting engine, which are included in the estimate. Several miles of difficult mountain wagon road and trails must be built, and a bridge be constructed across the South Fork at the power house. A screen of iron bars at the intake has been included in the estimate, also double screens at the penstock, to keep leaves and sticks from entering the pressure pipes. A telephone line of No. 12 wire, strung on the power line poles and equipped with instruments and cut-out switches at each of the substations, has been estimated upon, while a comfortable bunk house, with double roof and walls, library, dining room, kitchen, bathroom, and complete sanitary plumbing, which has been included, is regarded as a necessary adjunct, and a small ice-making plant and cold room piped for direct ammonia expansion, which have also been included, would add to the comfort of the employees.

Estimate of cost of power and pumping plants for generating and transmitting power from Kings River for the utilization of ground water in the valley.

Hydraulic works:		
Headworks and intake	$5,500	
Conduits	184,800	
Adits	7,700	
Sand traps	1,330	
Penstock and waste weir	3,478	
Pressure pipes (three steel pipes, each 30 inches in diameter, 3,200 feet in length, with gates and air valves)	59,691	
Hydraulic equipment (water wheels for the three generators and the two exciters, with governors, gates, and fittings)	27,000	
		$288,499

Buildings:
- Power house, foundations, and conduits
- Mess and bunk house
- Refrigerating plant
- Stable, workshop, and tools

Roads and bridges

Trails

Electric generation and conversion:
- Generating equipment and control (three generator horsepower each, two exciters for same, switch instruments, and installation)
- Transformers (ten of 600 horsepower each, 30,000 vol switches, etc.)

Transmission:
- Pole lines (45 miles of double pole line, four circuits terville, 45 miles distant, and 40 miles of distribution
- Centerville switch house
- Substation transformation (25 substations, each con four step-down transformers—one for reserve—tota ity 266 horsepower, with switches, etc., complet station designed to furnish the power for four pu stations)

Engineering and contingencies, 5 per cent

Total

Pumping stations, 100 at $4,057 (consisting of 50-hor 10-inch centrifugal pump and attachments, cement- four wells 90 feet deep, buildings, piping, etc.)

Engineering and contingencies, 5 per cent

Total

Recapitulation:
- Power generation and transmission
- Water development, i. e., 100 pumping stations

Total

The estimate on pumping plants is for a capa each, or a total of 500 second-feet, per 24 hours, per 24 hours from an average depth of 45 feet, acre-feet per annum (365 days), making the cos per acre-foot of annual capacity.

The estimated cost of operating the plants is

Estimated cost of operating power and pum

Interest, 6 per cent on bonded indebtedness
Taxes, 2 per cent on 60 per cent valuation
Depreciation and maintenance

ower house:		
One superintendent	$1,400	
Three attendants at $1,000	3,000	
Three helpers at $800	2,400	
One laborer	750	
One watchman	750	
Horses and stable	1,300	
Oil, waste, and supplies	2,400	
		*$12,000
le line:		
Two linemen	1,800	
Teams and supplies	800	
		2,600
mping stations:		
Ten attendants at $800	8,000	
Two inspectors at $1,000	2,000	
Horses, 20 at $150	3,000	
Oil, waste, and supplies	2,400	
		15,400
Total operating expenses		30,000
lministration and local expenses:		
One general superintendent	2,400	
One bookkeeper	1,200	
Office rent and sundries	1,400	
		5,000
surance and contingencies		5,000
		10,000
Total		157,611

Considering the load factor of the pumping system, i. e., the ratio the average load to the maximum load, to be 90 per cent, the annual mp output would be 328,500 acre-feet, on the basis of the use of plant for 328½ days, and the total cost of operating would amount in round numbers, $0.50 per acre-foot produced per annum. If plant were operated fewer days each year the cost per acre-foot oduced would be much greater.

CONCLUSION.

n order to appreciate the magnitude of the proposed development nay be compared with what has already been achieved with the vity flow of Kings River. The flow available during dry years is measure of irrigated acreage on which stable values can be maintained, since land with an uncertain water supply must fluctuate in ue as the seasons are favorable or otherwise. During 1898 the pply available was very deficient. Last year (1900) the profits from raisin crop alone in the Fresno district are reported to have been re than $2,000,000, and this industry, as well as the fruit, stock, l general farming interests, is dependent on the river, not partially t absolutely, for its existence. Practically all created values within area served by the water of Kings River are sustained by its

*Operatives to pay cost of board at mess house out of salaries.

flowage, and the aggregate of these values runs into millions of dollars. Plenty of additional land, of even better quality than that now under cultivation, is available if an assured water supply can be provided.

Making due allowance for seepage losses in conveying the pumped water, the annual amount available from the new supply would be 300,000 acre-feet, and the cost of supplying it would be only slightly in excess of the present charges for water from gravity canals in this locality.

The conditions described exist at many other places along the eastern slope of San Joaquin Valley, where there are many square miles of unused land, much of it possessing as great natural advantages as the tracts under cultivation at lower elevations, which a water supply would convert into a rich and productive country. Riverside is an example of what five years' development with water will accomplish. Notwithstanding the continued decreasing flow of the perennial supply due to the dry years 1895 to 1900, orange planting, which passed the natural limit of stream flow several years ago, has been steadily extended to outlying districts, and water development from well supplies has kept pace with the increasing requirements until the quantity available and the acreage served are much greater than ever before, and the best lands are now dependent on pump irrigation.

General attention now being directed toward the advantages possessed by California, it seems probable, under the pressure of increased population and the market demands which must follow, that another generation will witness the cultivation of every acre of land susceptible of irrigation in San Joaquin Valley, and in view of the possibilities herein suggested it does not appear unreasonable to believe that water will be provided for every acre that can be cultivated.

SUMMARY.

The important results of the investigations on Kings River are summarized in the following table:

Results of investigations for water development along Kings River.

Improvement.	Description.	Capacity, in acre-feet per annum.	Cost of installation.		Annual cost, per acre-foot, of interest and operation.
			Total.	Per acre-foot stored.	
Dusy Meadows reservoir.	125-foot dam	16,850	$538,860	$32.00	$3.10
Pine Flat reservoir	140-foot dam	78,197	1,750,000	22.38	2.06
Clarks Valley reservoir.	85-foot dam	120,499	1,331,025	11.05	1.04
Do	105-foot dam	217,196	2,206,822	10.15	.92
Long Meadow reservoir.	170-foot dam	25,334	713,715	28.00	2.64
Pumping plants	328½ days' operation per annum.	328,500	1,278,629	3.50	.50
Do	100 days' operation per annum.	100,000	1,278,629	12.78	1.43

The last column of the foregoing table gives the cost per acre-foot er annum of water delivered to the lands to be irrigated, a deduc- on of 20 per cent of the water stored being made for losses by vaporation and seepage in transit. The pumping plants being cated where the water will be used, no such deductions are made r them.

The Dusy Meadows and Long Meadow reservoir sites are not of ecial value, as better reservoir sites are available. The Pine Flat nd the Clarks Valley sites, however, are both of great value to the ings River irrigation districts. The storage work should be begun by uilding the Clarks Valley reservoir with the 85-foot dam. This ould be followed by the construction of the 140-foot dam at the Pine lat site. The height of the dam at Clarks Valley can be increased 105 feet or more in the future. Water from these reservoirs could ost advantageously be applied to the foothill lands between eleva- ons of 300 feet and 550 feet, where citrus fruits can be raised and here no water is now available.

The estimates show that the cheapest supply in the valley can oe btained by pumping with electric power generated by the river itself efore it reaches points of diversion or storage, provided the pump- ng plants are operated at least half the time. This pumped water ould be obtained most cheaply in the lower valley lands, where the ater plane has now risen to near the surface and where the longest iversions are necessary under existing canals. While the pumping lants might be used near the foothills the water supply there would ot be so large and the lifts would be greater, but the lands redeemed ould be more valuable.

During the high-water stages of the river, which last from March ntil the middle of June or the first of July, an abundance of cheap ater is now available by gravity for the irrigation of all of the lands ithin reasonable limits which are under Kings River. At present he use of the water is needlessly wasteful during that season of the ear. It is believed that if, in addition to this spring irrigation, water a depth of 1 foot could be furnished to the irrigated lands between he first of July and the end of November it would be sufficient to main- in them in a condition for the production of any crop. Assuming at the pumping plants will produce 200,000 acre-feet of water, there ill be available from that source and from the Clarks Valley and ine Flat reservoirs, with the lower dams, about 400,000 acre-feet of ater. If all the water that is diverted by the pumping plants and he storage reservoirs should be put onto new areas it would mean the ddition of 200,000 acres of irrigated land to the community.

In concluding it may be stated—

(1) The capacity of the canals diverting water from Kings River is pproximately 4,000 cubic feet per second.

(2) Ten years' records of the river show that the average flow for th month of August is 603 cubic feet per second and for the month o September 389 cubic feet per second.

(3) The irrigable area is very great.

(4) Probably the most valuable areas in Fresno and Tulare counties are the foothill lands upon which citrus fruits can be grown between the 300-foot and the 600-foot contours of elevation. These lands are without water rights and can be irrigated from the reservoirs described herein.

(5) Pumping plants can be established and operated which will furnish 1,000 acre-feet of water per day at a cost not much greater than that now paid for gravity water from the canals, to supplement the present summer supply or to extend the irrigated areas.

(6) The operation of the pumping plants will partially if not wholly prevent the rising of alkali to the surface of irrigated lands.

(7) One hundred and ninety-eight thousand six hundred and ninety-six acre-feet of water now wasting annually can by storage be conserved at prices well within commercial limits.

(8) A good water right will add $50 per acre to the value of dry lands in the valley and $90 per acre to the value of lands in the foothills.

(9) All of the works included in the table on page 96 are feasible and safe from an engineering point of view.

ACKNOWLEDGMENTS.

Acknowledgments are due to Mr. H. E. Green, who had charge of one of the field parties and rendered excellent service in that capacity, especially in the arduous and dangerous survey of the canyon of the Middle Fork of Kings River, and who also assisted in the preparation of the estimates and plans for the dams and power conduit; to Mr. J. H. Quinton, who assisted, as consulting engineer in preparing the plans and estimates; to Mr. Lewis A. Hicks, who made the estimates of the cost of installing the electrical machinery and the pumping plants, which from his experience in that line of work on Kern River are of special value; to Mr. Thomas Means, assistant in the Division of Soils of the United States Department of Agriculture, who has given valuable information concerning the alkali conditions; to Mr. E. G. Hamilton, topographer from the United States Geological Survey, who was in charge of the reconnaissance party; to Mr. Louis Mesmer, who compiled the data concerning the wells and the tests thereof; and to Messrs. W. H. Ingells and L. A. Nares, who have furnished a great deal of general information concerning the local conditions and the irrigated areas.

ADDENDA.

In the summer of 1901 a series of measurements of some of the canals taking water from the north bank of Kings River and east of Centerville were made for Mr. L. A. Nares, general agent of the Fresno canal. This is nineteen years subsequent to the measurements made by Mr. Grunsky, and the results are in marked contrast with those obtained by him. Evidently the continued irrigation practiced during the interval has raised the ground-water level so that it is largely supporting the water in transit in the canals. While in some instances gains in the volume of water are reported, it is believed by the writer that these must be the exception instead of the rule, for the canals are normally higher than the lands irrigated, and there can not be a gain unless the plane of saturation is higher than the surface of the flowing water.

These measurements are of interest, but owing to continued diurnal fluctuations in both the river and the canals absolute results can only be obtained by continuous records of water heights at rating stations.

Summary of measurements made in Kings River canals in August and September, 1901, to determine loss or gain by seepage and evaporation.

No. of measurement.	Name of canal.	Locality.	Distance.	Gain or loss.	
			Miles.	*Sec.-feet.*	*Per cent.*
1	Centerville and Kingsburg canal.	Centerville to Sanger	7	−20.00	− 5
2	Fowler Switch canal	Centerville to Collins Gate	9	+ 6.00	+ 2
3	do	Head gate to Centerville	2	+	+
4	do	Centerville to Collins Gate	9	− 9.57	− 8
5	Centerville and Kingsburg canal.	Centerville to Sanger	7	−33.00	−12
6	Gould canal	Holland Flume to Kutner Colony.	11	+ 2.25	+ 1
7	do	do	11	+ 1.50	+ 2
8	Main canal	Long Cut and Limbaugh Gate.	10	−27.65	− 7

NOTE.—All of the measurements except Nos. 4 and 5 were made with a current meter. Plus sign (+) indicates gain, and minus sign (−) indicates loss.

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DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 59

DEVELOPMENT AND APPLICATION OF WATER RESOURCES
SAN BERNARDINO, COLTON, AND RIVERSIDE
QUAD., PART I—[illegible]

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation prepared by the United States Geological Survey since 1888.

1888.

First Annual Report of the United States Irrigation Survey, 1888; octavo.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888-89. Contains a statement of the origin of the Irrigation Survey; a preliminary report on the organization and prosecution of the survey of the said Tenth Annual Irrigation, and report of work done during 1889.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of Nevada and of the engineering questions carried on by the Irrigation Survey during 1890; statement of the Director of the Survey to the House Committee on Irrigation; appendix containing a bibliography of irrigation literature. Illustrated by 20 plates and figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 30 plates and 136 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 58, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 61, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 103, Irrigation in Montana; No. 101, Irrigation in Idaho; No. 102, Irrigation in Nevada; No. 100, Irrigation in Oregon; No. 104, Artesian wells for irrigation; No. 106, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin, September 9, 1892; quarto, 74 pp.

Contains tabulations showing the total number, average size, etc., of irrigated farms in the United States and average size of irrigated farms in the principal regions. Includes a summary of farms irrigated, character of crops, value of irrigated lands, the cost of irrigation, the investment and profits, together with a review of the water supply, a description of irrigation by artesian wells. Illustrated by colored maps showing location and relative areas of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891-92, Part III, Irrigation, 1893; octavo, 456 pp.

Contains 11 papers. "Water supply for irrigation," by F. H. Newell; "Irrigation engineering," and "Engineering results of the Irrigation Survey," by J. B. Wilson; "Construction of topographic maps and contour and survey of reservoirs," by A. H. Thompson. Illustrated by 67 plates and 138 figures.

A geological reconnaissance in central Washington, by Israel Cook Russell; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the several plains of the Columbia in the same area, with special reference to the conditions of artesian supply.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894, quarto, 288 pp.

Contains a general description of the condition of irrigation in the United States, area irrigated, cost of works, water rights and modes and conditions, the water supply, value of water, artesian wells, reservoirs and other matters. Each State and Territory in order gives a general description of the condition of agriculture, irrigation and the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892-93, in two parts; Part II, Accompanying papers, 1894; octavo, 397 pp.

Contains papers on "Pumping plants of the region United States," by W. [illegible]; "Natural mineral waters of the United States," by A. C. Peale; "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 59

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

;ELOPMENT AND APPLICATION OF WATER NEAR SAN BERNARDINO, COLTON AND RIVERSIDE, CAL

PART I

By JOSEPH BARLOW LIPPINCOTT

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., June 29, 1901.

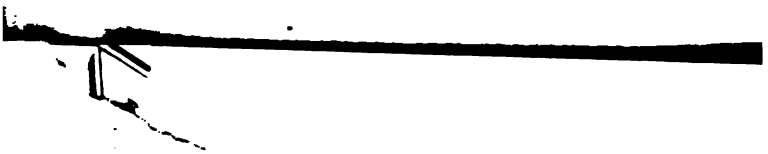
SIR: I have the honor to transmit herewith a manuscript concerning the development and application of water in southern California, prepared by Mr. J. B. Lippincott, resident hydrographer for this Survey in California. This paper describes the general conditions of water supply in an important and densely populated agricultural area, where water has probably the greatest value for irrigation of any part of the United States. The data are of particular interest because of the development made during the series of dry years which culminated in 1890. Every possible expedient was resorted to for economizing or increasing the supply of water; tunnels were driven into the hills, dams were built to bed rock in the canyons, and wells were dug or drilled throughout the valleys. Almost every conceivable device for pumping water has been employed and great ingenuity displayed in bringing water to the orchards and more valuable crops.

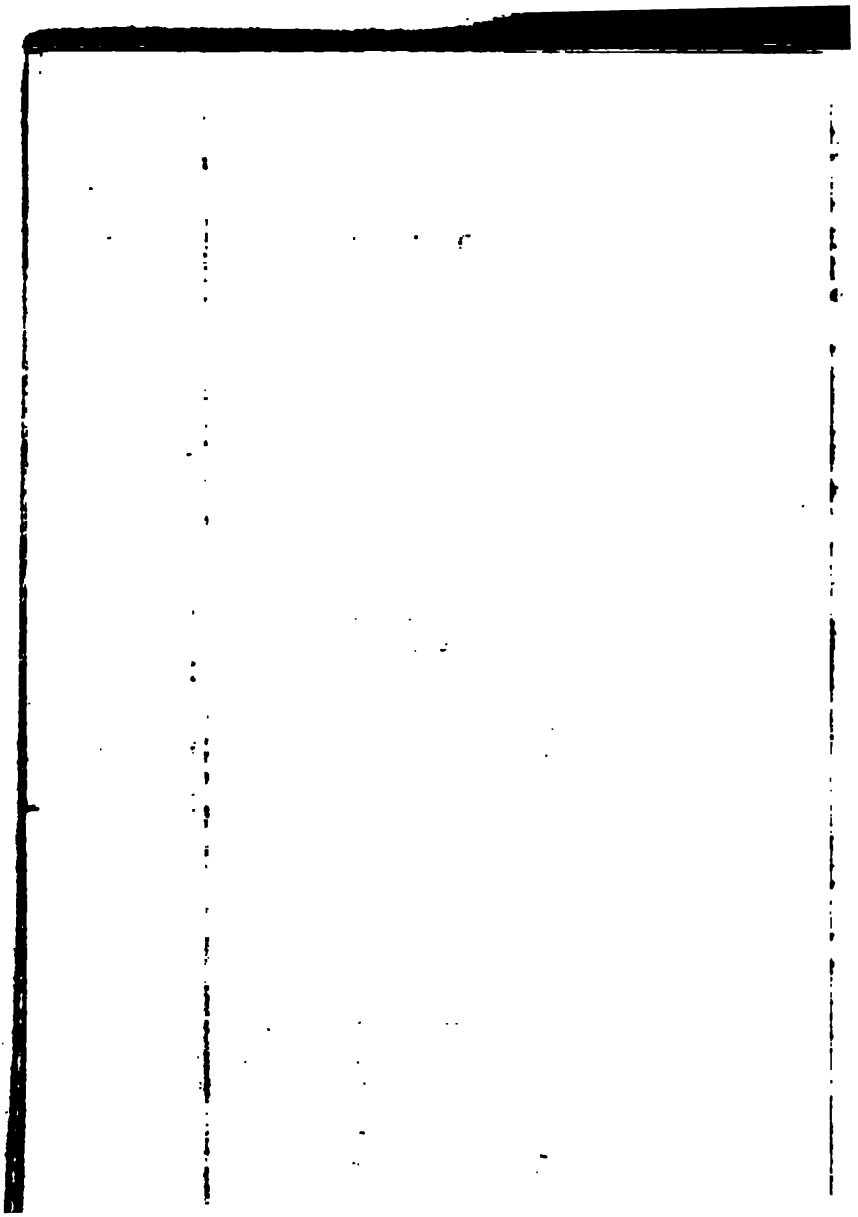
The details of some of the works and wells have been brought together by Mr. Lippincott and form an exhibit of results accomplished under conditions where water has great value. The results are instructive, as showing what may be done in other parts of the United States under favorable conditions of climate and soil, and have peculiar interest in any consideration of the extent to which the Arid Lands can ultimately be redeemed by irrigation.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.





ENT AND APPLICATION OF WATER NEAR SAN ARDINO, COLTON, AND RIVERSIDE, CAL.

PART I.

By JOSEPH BARLOW LIPPINCOTT.

ERAL LOCATION AND TOPOGRAPHY.

uniformity and mildness of its climate, the grandeur of its scenery, and the great variety and vigor of its n furnished with moisture by irrigation, southern Cali- me the pleasure ground of the United States. In its alleys, lying between snow-capped mountains and a efinement, and wealth have combined to make beauti- ie narrow strip of land lying between the mountains 'ast becoming the Riviera of America. San Bernardino rden, furnishing many varieties of deciduous and semi- for Eastern and domestic markets. Riverside and he two principal centers of fruit production.

s protected from the cold winds off the desert on the by the Sierra Madre and San Bernardino Range, the he crests of which vary from 5,000 to 10,000 feet. To west the valley is inclosed by low mountains, which ry coast range, the highest peaks of which are in the ge to the south, the lowest in the San Jose and Puente st. The latter separate San Bernardino Valley from lley and the Santa Ana coastal plain. San Bernardino at resembles a right-angled triangle, the apex being at e Santa Ana River leaves the mountain range, the base ı Corona to Lordsburg, 24 miles distant, the right angle a, and the height 32 miles. The area of the valley is s. The streams enter it from the north and east, com- ierra Madre and the San Bernardino Mountains, with f San Timoteo Creek, which discharges about 1 second- , and Temescal Creek, which irrigates 3,600 acres.

le district is on the south side of the valley and is irri- urn water, from pumping plants, and from artesian

wells. The city of San Bernardino and its surrounding neighborhood are similarly supplied, supplemented also by Lytle Creek. Corona is irrigated from Temescal Creek and from local wells, supplemented by a pumping plant and pipe line from the water-bearing lands of San Jacinto Valley. All of the remaining orchards and gardens of San Bernardino Valley are on the northern and eastern edge of the valley and are supplied from local mountain drainage basins.

During years of average stream flow the duty of water for citrus fruits may be taken at from 5 to 8 acres to the miners' inch (0.02 second-foot), continuous flow, when good service is rendered, and double that area when used for deciduous trees.

All of the streams issuing from the north side of the valley have assisted in building up a bench-like mesa of débris cones of granite material, which varies in elevation from 800 to 1,200 feet above the thalweg of the valley. The northern rim of the valley at the foothills is at an elevation about 2,000 feet above sea level and the southern rim at an elevation of approximately 1,200 feet. On the southern side of the valley the mesa which lies next to the foothills is formed to a large extent from disintegrated granite mingled with red clays from San Timoteo Canyon and adjoining hills. Upon this bench are Riverside and Redlands, and it is from the red soil that the latter district derives its name. The Riverside bench is from 100 to 300 feet above the river bed and from 850 to 1,000 feet above sea level. It is 20 miles long and about 5 miles wide.

Water is the life blood of the land. Without it there can be no substantial growth, except occasional crops of grain, and this region would become a semidesert. We therefore find (see map, Pl. I) the towns and orchards clustered around the mountain edges, the canyons from which the streams issue, or in the lower depressions of the valley toward which the underground and return water from irrigation gravitate, to appear again for use on the surface, as at Colton and Rincon. The intermediate lands remain mostly unused and uncultivated, a few cattle to the section or an occasional crop of grain being all they will support. The highly productive portion of the valley is limited by the amount of water that is available for irrigation. All of the summer and much of the normal winter flow of the streams has now been appropriated and diverted, and it would seem that the valley had reached its limit of irrigated land from that source. However, in the lower valley lands the extensive saturated gravel beds will be drawn upon to supplement the surface supply, especially during dry years. The precipitation occurs almost entirely between November and April, and in normal years varies from 10 inches in the valley to 50 inches on high mountains. The minimum is as low as 33 per cent and the maximum as high as 200 per cent of the mean. The discharge of the streams is relatively large

n winter and low in summer. The increase of the summer water upply is dependent upon the construction of reservoirs in the mountains, to store the winter storm water, or upon the development of ater by wells or excavations in the valley lands.

The map accompanying this report (Pl. I) shows, by shaded areas, he land actually under irrigation and supplied or partially supplied ith water during the summer of 1900. No effort has been made to listinguish between good and poor water supplies. The irrigated areas ere determined by actual field observations, those in the Redlands uadrangle by Mr. Louis Mesmer, and those in the San Bernardino uadrangle by Mr. C. J. Roney, both of Los Angeles. The various rigation canals and the principal distribution lines are also indited on the map, as well as the locations of the power plants on Santa na River and Mill Creek, the approximate location of the water ane for the summer of 1900, and the locations of the wells. The mbers on the map correspond with the numbers of the wells in the ble on pages 115 to 134 (Part II). Where isolated wells occur and e information is not sufficient to contour the water plane, its eletion is given (black figures) on the map.

SOIL.

The soil of the valley is of two distinct classes, the bench or delta te lands around the rim of the valley and the moist bottom lands. he former merge from mere piles of rocky bowlders and sand conining little humus or soluble matter but which are capable of growg orchards, to sandy loams such as are found around Riverside. hey are very deep and apparently of the same chemical composition the lower strata as at the surface. They are warm and porous, and such surface gradients that they are well drained, so that there is danger to either the crops or the health of the cultivator from a sing and stagnant water plane with its accompanying alkali. Prof. W. Hilgard, professor of agriculture at the University of Calinia, furnishes the following analyses of the Riverside soil and ubsoil:

Analyses of soil and subsoil at Riverside.

	Soil, depth 12 inches.	Subsoil, depth 9 to 10 feet.		Soil, depth 12 inches.	Subsoil, depth 9 to 10 feet.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
arse materials	20.000	23.000	Alumina	5.298	5.078
ne earth	80.000	77.000	Phosphoric acid	.141	.159
			Sulphuric acid	.001	.001
soluble matter	76.410	75.445	Water and organic matter	1.600	1.440
luble silica	8.204	8.066			
ash	.869	.928	Total	99.947	100.172
da	.293	.360	Humus	20.000	
me	1.598	1.727	Available inorganic matter	64.000	
agnesia	1.325	1.581	Available phosphoric acid	.015	
own oxide manganese	.040	.041	Hygroscopic moisture absorbed at 16°C	1.77	2.160
roxide iron	4.200	5.338			

In the lower portions of the valley, where the water comes to the surface, the land is moist enough for cultivation without irrigation. Fields of alfalfa are thus grown around San Bernardino, Colton, and Rincon, and it is upon land of this character that the Chino beets are raised. Where the subdrainage is poor the continuous evaporation from the surface of the soil of water that is but slightly charged with sodium, carbonate, and sulphate will ultimately produce an alkali soil. This has occurred frequently in these localities. It is claimed, however, that the sugar beet will thrive on land somewhat alkaline, and this is said to have been demonstrated at Chino. In these bottom lands some adobe is found, but it does not cover extensive areas. The remedy for this alkali condition will probably be found in drainage and in the use of gypsum.

CLIMATE.

It has been said of southern California that every township has a distinct climate. It has taken years of time and the expenditure of thousands of dollars to determine the frost line. There is no protracted cold weather in San Bernardino Valley. A temperature of 26° F. maintained for several hours will freeze and ruin an orange or lemon crop, a temperature of 18° will kill young trees, and a temperature of 14° maintained over night is sufficient to kill old trees. These low temperatures are reached only during the night. The isotherms follow topographic contours within certain limits. The frost and cold settle into the relatively low lands, but other local conditions tend to modify this physical phenomenon.

The air over the desert east of the mountains is raised to a relatively high temperature during the daytime and is forced upward. In the citrus belts frost usually occurs when a high barometric pressure exists over the desert, producing winds away from that locality. The air currents that are forced over the higher mountains are chilled and frost is found along the depressions of the canyons leading from their crests, while the drafts of desert air passing through the low passes are warmer. The areas affected by frost vary from year to year and no exact isotherms can be drawn for all years. After entering the valley the cold air, being relatively heavier, gravitates to the lower levels. The north wind from the Cajon Pass, which protects Rialto, Riverside, and Bloomington, seems to force the colder air which gravitates toward the lower portions of the valley around Colton into the extreme lower portion of Santa Ana Valley.

Up to elevations of 2,000 feet the relatively high lands are free from frosts and the relatively low lands are subject to it. For instance, in the Del Rosa and West Highlands districts the lands south of the track of the Southern California Railroad are considered unsafe for oranges while those above it are relatively free from frost. The

hborhood of the town of San Bernardino has been largely aban-
d as a citrus district and converted into dairy, vegetable, and
luous-fruit farms. This determination of the frost line is a sub-
of vital importance to those intending to cultivate citrus fruits,
can not be studied with too much care. After orchards have
developed it has often been found that they are not within the
nal belt, and vigorous efforts have been made to remedy the evil.
'mometers which ring alarms when the mercury drops below 32°
been constructed and placed in the orchards. A common prac-
is to burn brush or coke, or otherwise produce a smoke, so as to
the temperature a few degrees and prevent freezing. Wind, if
e be any, tends to mitigate the frost. In some localities ignited
of crude oil or distillate, 15 to the acre, have been tried and have
d the local temperature 3°, but even this is uncertain, for the
l blows away the warmer air and the burning oil smuts the trees.
n this method is adopted oil tanks are placed in the orchard and
ibution pipes are laid to the jets throughout the groves. A unit
ater in freezing gives off sufficient latent heat to raise the tem-
ture of an equal unit of water 142° F. In order to use the latent
thrown off in freezing, Mr. A. J. Everett, of Riverside, tried dis-
ging sprays of water above the trees when the temperature of the
osphere fell below 32°. The result, however, was a failure, the
s becoming coated with ice and the limbs being broken, with no
ltant benefit.

he most successful efforts in the protection of orchards from frosts
e been those of Mr. Everett, who covered 15 acres of orchard with
fencing, half the space being open, as shown in Pl. II. The day
perature under the screen is found to be as high as that outside.
theory is to hold the day temperature of the earth under the
en as long as possible at night, or in other words to impede radi-
n. The shade afforded by the screen also tends to prevent rapid
ring of the fruit and the expansion of the liquid in the fruit cells
unrise, which bursts the cells and spoils the fruit. Without fires
er the screen the night temperature is held 6° above that of the
ide atmosphere. In one instance, with an outside temperature of
and with ten coke fires to the acre distributed under the screen
ire pots holding about 1 cubic foot each, the temperature under
screen was kept at 29° during the night, and it is said that it
ld have been kept at 32° except for carelessness. In the fall of
, 75 trees in the coldest portion of an orchard were covered and
crop was saved. Part of the trees were covered with canvas over
lath and part with lath only, the results being equally bene-
l. Outside the screen both crop and trees were frozen and in
e instances the trees were killed. Inside the screen the St. Michael
nges, the most delicate, were saved. The crop, however, does not
en as quickly under the screen as outside. With lumber at $20 a

thousand the cost of building the screen is approximately $425 to the acre. The uprights are 3 inches by 4 inches by 15 feet high, and are set 21.2 feet apart. The top members are two 1-inch by 4-inch boards edged in T shape. The top of the screen is of lath commonly used for chicken-yard fences, openings the width of the lath being left between them. The high cost of this cover has prevented its being generally used.

A more even temperature exists nearer the seacoast than in San Bernardino Valley, and for winter vegetables and deciduous fruits that may be the better location, but not for citrus fruits. In the interior valley the temperature during the summer rises from 30° to 40° higher than on the coast, and high temperatures are necessary for the production of a sweet fruit. The cooler coast temperatures and fogs also tend to cause the citrus fruits to grow a thick-skinned, pulpy-celled lining. The higher temperatures are also unfavorable to the scale pest, which is the insect enemy to citrus fruits. The black scale exudes a sticky substance, which falling on the leaves and fruit retains the dust and gives the trees and fruit a dirty appearance. In the interior valleys the scale is not found. Generally speaking, in southern California the best citrus fruit is grown 30 or more miles from the coast, on the western slope of the mountains, and at elevations from 600 to 1,800 feet above sea. The conditions mentioned have greatly restricted the area where citrus fruits can be grown at a profit, and this area may be said to be decreasing rather than increasing. The general development of the country and improved transportation facilities are tending to enhance the value of really first-class citrus lands. It must be remembered that the determination of the frost line has been a slow process, but it is gradually being located, and the newer groves are planted in more propitious places. The groves located within the frost belt are chiefly old seedlings, now in full bearing, so that the loss from freezing is relatively much larger now than it will be ten years hence, for the old orchard lands that have been found frosty will be put into different crops or their water rights be transferred to other and better located lands. It is safe to say that throughout San Bernardino Valley much more land will be found adapted to this class of horticulture than the water supply will serve.

From the following tables of rainfall and temperature it will be seen that during the summer, or growing season, there is an absence of rain. In fact, from April 1 to November 1 there is practically continuous sunshine. The atmosphere also is very dry. These two conditions produce a rapid plant growth when water is abundantly supplied by irrigation. Vegetation develops with much greater rapidity under these conditions than at similar latitudes in the Eastern States.

.NERAL VIEW OF FRAMEWORK OF SCREEN FOR PROTECTING ORCHARDS FROM FROST AT RIVERSIDE.

B FROST SCREEN AS SEEN FROM BENEATH.

Table of temperatures, in degrees Fahrenheit, at Riverside.

Year.	Jan.		Feb.		Mar.		Apr.		May.		June.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
1890	[illegible]											
1891, mean												
1892, mean												
1893, mean												
1894, mean												
1895, mean												
1896												
1897												
1898												
1899												
1900												

Year.	July.		Aug.		Sept.		Oct.		Nov.		Dec.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
1890	106	50	105	52	104	49	97	36	85	36	72	27
1891, mean		58.2		57.8		54.0						
1892, mean		53.1		54.3		50.4						
1893, mean		54.8		54.7		55.5						
1894, mean		55.2		54.4		51.6						
1895, mean		54.8		55.1		51.6						
1896	91.65	78.02	90.60	57.90	87.64	54.56	83	42	72	34	71	27
1897	102	50	108	52	100	46	92	35	82	34	72	26
1898	105	52	111	51	112	47	100	41	83	34	74	26
1899	103	49	103	49	105	52	94	40	84	36	74	27
1900	[illegible]											

*Authority, Weather Bureau.

Record of precipitation, in inches, at Riverside.

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1880-81	0.00	0.00	0.20	2.26	0.48	0.25	1.30	0.74	0.03	0.00	0.00	0.00	5.26
1881-82	.10	.40	.25	.40	1.70	1.40	1.08	.72	.08	.18	.00	.00	6.31
1882-83	.00	.13	.29	.20	.09	.83	.89	.26	.25	.00	.00	.00	2.94
1883-84	.00	.97	.00	2.25	.84	7.94	6.56	1.67	1.99	.32	.00	.00	25.74
1884-85	.00	.12	.12	2.56	.77	.00	.01	2.15	.24	.00	.00	.00	5.97
1885-86	.00	.02	1.34	.62	2.68	1.38	1.95	1.43	.00	.00	.00	.00	9.42
1886-87	.00	.00	.54	.04	.13	3.30	.02	1.70	.17	.02	.00	.00	5.92
1887-88	.00	.75	.87	.85	4.17	1.05	3.84	.18	.05	.00	.00	.00	11.71
1888-89	.00	.00	2.83	3.37	.87	1.30	5.10	1.83	.25	.00	.00	.00	15.55
1889-90	.09	1.35	1.82	7.10	4.44	1.96	.60	.06	.00	.00	.00	.05	18.30
1890-91	.79	.13	.32	3.21	.13	6.36	.40	1.04	.46	.00	.00	.00	12.84
1891-92	.13	.03	.00	1.29	.00	2.60	1.07	.00	1.32	.00	.00	.00	6.44
1892-93	.00	.29	.28	.94	3.01	1.95	5.71	.29	.04	.00	.33	.00	12.70
1893-94	1.27	1.08	.67	2.05	.69	.33	.70	.00	.00	.00	.00	.26	7.05
1894-95	.20	.05	.00	5.22	6.48	1.09	2.54	.29	.26	.00	.00	.00	16.13
1895-96	.00	.00	1.25	.24	1.72	1.00	3.16	.56	.58	.00	.01	.02	8.54
1896-97	.00	2.07	1.48	.92	3.38	3.07	1.62	.03	.03	.00	.00	.04	12.64
1897-98	.09	1.67	.02	.95	1.41	.16	.62	.24	.30	.00	.00	.00	5.46
1898-99	.03	.00	.00	.62	1.81	.52	1.13	.10	.08	.53	.00		5.00
1899-1900	.00	1.05	.68	.58	1.11	.00	1.11	1.32	1.04	.00	.00	.00	6.89
Mean													10.00

*Hall.

Record of precipitation, in inches, at San Bernardino.

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	T
1885-86	0.00	0.39	4.36	1.20	6.34	2.52	4.18	2.36	0.32	0.16	0.00	0.00	
1886-87	.00	.00	.11	.61	.39	6.44	4.41	1.90	.42	.22	.11	.04	
1887-88	.09	1.17	2.29	1.91	4.01	3.60	3.41	.58	.52	.03	.00	.00	
1888-89	.00	.05	4.12	4.64	.93	1.50	6.55	2.05	1.13	.00	.17	.63	
1889-90	.11	2.30	2.23	10.85	5.44	2.52	.89	.00	.31	.00	.13	2.16	
1890-91	.88	.58	1.27	3.02	.00	7.78	.06	.53	1.67	.00	.00	.91	
1891-92	.93	T.	T.	1.67	3.24	3.30	1.75	.37	2.10	.08	.00	.00	
1892-93	.00	.16	1.02	2.23	4.53	5.37	8.00	.48	.03	.00	.20	.00	
1893-94	.05	1.05	.30	2.28	1.26	.88	1.15	.40	.56	.00	.00	.16	
1894-95	.37	.15	.00	7.25	7.39	1.14	3.44	.64	.44	.00	.00	.00	
1895-96	.00	.00	1.14	.66	2.02	.00	2.92	.37	1.00	.00	T.	.17	
1896-97	.00	2.10	.98	1.09	3.40	5.40	3.41	.08	.01	.00	T.	.00	
1897-98	.13	2.10	.21	.57	2.10	.60	.97	.48	1.08	.00	.00	.00	
1898-99	.00	.03	.05	.44	2.03	.51	3.22	.07	.19	.05	.00	T.	
1899-1900	.01	.81	1.47	.84	.92	.00	.12	.02	.00	.00	.50	.00	
Mean													1

Record of precipitation, in inches, at Colton.

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	To
1885-86	0.00	0.00	1.92	0.52	2.78	0.40	3.54	0.50	0.00	0.00	0.60	0.00	
1886-87	.00	.00	.80	.00	.21	3.64	.00	1.94	T.	.00	.00	.00	
1887-88	.00	.00	.70	.80	1.43	2.15	3.68	.43	.00	.00	.00	.00	
1888-89	.00	.00	2.37	3.26	.86	.88	4.47	1.02	.60	.00	.00	T.	1
1889-90	.04	1.59	1.26	7.41	.94	1.15	.50	.00	.00	.00	.00	.06	1
1890-91	.67	.00	.19	2.45	.00	6.48	.25	.80	.90	.00	.00	.00	1
1891-92	.00	.00	.00	.87	2.27	3.36	.80	.24	1.44	.00	.00	.00	
1892-93	.00	.....	.90	1.45	2.40	2.91	6.64	.16	.00	.00	.30	.00	1
1893-94	.00	1.18	.22	1.93	.20	.55	2.00	.10	.50	.00	.00	.00	
1894-95	.45	.15	.00	5.70	2.88	1.00	2.94	1.08	1.05	.00	.00	.00	
1895-96	.00	.00	1.16	.00	.10	.00	2.91	.25	.38	.00	.00	.10	
1896-97	(?)	2.28	.94	1.11	3.52	3.96	2.70	.00	.15	.85	.00	.00	1
1897-98	.00	2.20	(?)	.30	1.48	.23	.80	.10	.34	.00	.00	.00	
1898-99	.00	T.	T.	.45	1.57	.45	1.55	.00	.00	T.	.00	.00	
1899-1900	.00	.00	1.96	.55	1.06	.00	.....	.....	.....	.....	.....	.....	
Mean													1

T indicates trace.

CROPS.

The distinctive crop of San Bernardino Valley is citrus fru Oranges predominate, followed next by lemons, and of late years grape fruit has become a popular product. The favorite variety orange is the navel, a seedless fruit which has been highly develo at Riverside. Other varieties are the Mediterranean Sweet, the Michael, and the Malta Blood. These all are budded fruits on se ling roots. Pl. III, *A*, shows a bearing grove of navel oranges Riverside. The seedling orange that was at first planted extensiv is not now popular. Its value is less than half that of the budd fruit. The seedling tree is larger and longer lived than the budd varieties, but the fruit is not so sweet nor so highly flavored. T Eureka and Lisbon are the favorite varieties of lemon. The orar trees bloom in March and the crop ripens from December 1 to May Some varieties of lemon trees are constantly ripening fruit, a heav crop being borne in the winter. Olives, almonds, prunes, aprico peaches, pears, and wine, raisin, and table grapes are all grown in t

A. NAVEL ORANGE GROVE AT RIVERSIDE, SAN BERNARDINO VALLEY.

B MAGNOLIA AVENUE, RIVERSIDE.

district to perfection and in large quantities. Generally speaking, these are planted where the frost line debars the growth of citrus fruits. The citrus trees being constantly in fruit or blossom require more water than deciduous trees; therefore where the water supply is limited deciduous fruits are the more popular crop.

In the moist lands of the river bottoms near San Bernardino dairy farming is generally practiced, the products being disposed of to the orchardists and the local towns. In the moist lands near the lower narrows of the river beets are grown without irrigation, and at Chino there is a beet-sugar factory. The beets grown here contain from 16 to 18 per cent of saccharine matter, which is very high compared with those grown in Eastern localities.

An interesting feature of this district is the care that is taken of the orchards. No weeds are permitted to grow, and the lands are evenly sloped to true grades. Efforts are made to carry out artistic and neat effects in the homes, the streets, the canals, and the groves, as will be seen in Pls. III, *B*, and IV.

In the eleven years prior to 1898 Riverside shipped nearly 7,000,000 boxes of oranges, which at fair figures means an average income of $1,000,000 a year. With the present condition of the orchards an income twice as large may fairly be expected. There were 4,000 carloads of citrus fruits shipped from Riverside during the season of 1897–98. The annual yield there in 1899 is said to be about one-third of the entire output of the State. Navel oranges during the last ten years (1890–1900) have averaged at Riverside $1.50 a box,[a] and Mediterranean Sweets $1.25 to $1.50 a box; Malta Bloods and St. Michaels have brought somewhat higher prices. The production of the lemon has not been very popular in the past, as the method of curing it was not well understood. This problem has now been mastered, however, and the well-cured California lemon ranks with the best Sicilian product. The United States imports $5,000,000 worth of lemons yearly, and California is after the market. Lemons are worth about $1 a box, and the yield of trees fifteen years old is from five to eight boxes each.

It is difficult to say what the profits of citrus fruit culture are. It is a question of the survival of the fittest. The man whose crop is frozen every third year, or who has but half a water supply in dry years, or whose trees are of a low grade, is not among the fittest. For financial success these conditions must be relatively perfect. With these conditions satisfactory he should average 10 per cent net on his investment at the end of fifteen years. In the past, when prices were higher and competition less severe, there doubtless have been many cases where as much as $500 or $1,000 per acre per season has been produced from an orchard, and it is possible that these figures may again be reached, but they are not a proper basis for estimates. It costs in the neighborhood of $900 an acre to get a citrus orchard in bearing condition, including land, water, and interest on the invest-

[a] Prices are f. o. b. cars.

ment. Under favorable conditions a ten-year-old orchard should duce $200 gross and $100 net per acre. Almost without exceptio policy of living in the Eastern States and paying kind friend parental corporations to attend to an orchard results in the lo money and mutual respect. Under the best conditions it takes or more years of hard, patient, and intelligent work to get an or orchard on a paying basis. It is not a poor man's business. W success comes it is an ideal life to spend one's days among the go fruit in a pleasant land. It is a country life surrounded by cultiv neighbors and with most of the conveniences of the city.

In the Eleventh Census (1890), under Agriculture by Irrigat page 33, is the following statement:

> In average value on June 1st, 1890, of farm land irrigated, $150 per acre, fornia leads the list, Utah coming second, with $84.25 per acre. This fi exhibits perhaps better than any other the extraordinary values of land in fornia arising from its utilization for orchards and vineyards. The value of ranges from $300 to $500 and upward per acre, thus greatly raising the ave value of irrigated land, which of course also includes the great areas devot the raising of hay crops. The same fact is exhibited, though perhaps n clearly, in the high average value of products per acre in 1889 and in the average first cost of water rights, $12.95 per acre, and average value of the 1890, $39.28 per acre, a high cost and value being justified by the enormous p resulting from successful fruit culture. In short, it may be said that the c tions in California, although by no means perfect, have produced such results they have served to stimulate development in all parts of western United St Much is still to be accomplished by the subdivision of the great irrigated hold this state standing first in the aggregate area and average size of irrigated ings of over 160 acres in area. These, although embracing 61.88 per cent o total area irrigated are not of as great relative importance as in Nevada and ming, where the large farms are devoted mainly to the forage crops.

What is true of the State as a whole is doubly true of San Ber dino Valley. There irrigation and horticulture have probably rea higher planes of development than in any other irrigation distric

During the season of 1900–1901 southern California shipped 7,664 boxes of oranges and 908,856 boxes of lemons, worth to the gro $5,750,000.

Pl. IV, *A*, is a view of an orange grove in San Bernardino, sh ing a method of irrigating by throwing up the earth so as to const around each tree a basin in which water is turned and allowe stand until absorbed. Pl. IV, *B*, shows an irrigation canal of Riverside Water Company near Riverside.

WATER SUPPLY.

The rain clouds from the Pacific Ocean, passing in large part the lower intervening foothills and valleys, are condensed on b forced up and over the high crest of the Sierra Madre and the Bernardino Mountains, which are from 6,000 to 11,000 feet in elevat

The precipitation in the mountains occurring in the winter mo

A. ORANGE GROVE, SHOWING METHOD OF BASIN IRRIGATION.

B. CANAL OF RIVERSIDE WATER COMPANY NEAR RIVERSIDE.

is largely in the form of snow, part of which does not melt until the spring months, thus maintaining the flow of the streams up to the first of May at a relatively large volume. Occasional thunderstorms visit the higher mountains in the summer. They are very violent and cause a sudden rise of the streams, which is not maintained. The rainfall of the valleys is about 15 inches annually, occurring in nongrowing months, there being little or no precipitation from April 1 to November 1. The grades of the drainage lines in the mountains are very steep, affording little opportunity for storage reservoirs. This is particularly unfortunate, as more than three-fifths of the stream flow occurs during the winter months. The Bear Valley reservoir is the one exception. It has a capacity at the 60-foot contour of 40,476 acre-feet, or 5,590 miners' inches (111.8 second-feet), flowing for six months. This water is taken to the Redlands and Highlands districts. The works are described in the Nineteenth Annual Report of the United States Geological Survey, Part IV, pages 584 to 598.

With the exception of San Timoteo and Temescal creeks all of the valley streams rise in the Sierra Madre and supply more than 90 per cent of the water used in the valley. There are three classes of water supply available, viz, surface streams, underground water, and water held in storage reservoirs. The principal stream of southern California is Santa Ana River. From the mouth of its mountain canyon to a point 4 miles east of Colton it has a grade of 100 feet to the mile, while below that point, to the lower narrows, the grade is but 27 feet to the mile. City Creek has a grade for the first 5 miles below its canyon of 100 feet to the mile, Lytle Creek a grade of 150 feet, and San Antonio and Cucamonga creeks a grade of 200 feet. The grades of these streams are still heavier in their granitic mountain canyons, and during flood stages they have carried down masses of sand and bowlders and built delta-like benches or mesas far out into the center of the valley, the finer material being conveyed farthest. In this way the valley has been filled to a depth of several hundred feet. In their course over these deltas the winter floods largely disappear in the detritus near the rim and penetrate in part under these layers of clay, thus forming reservoirs of ground water of unknown but great capacity. The water diverted for irrigation at the mouths of the canyons is also distributed upon porous soils, on steep grades, and with other underground bodies of water gravitates on the heavy prevailing slopes toward the center of the valley. One and a half miles northeast of Colton is an outcropping of clay known as Bunker Hill. This is a point on a low clay ridge bearing approximately S. 40° E., connecting with the foothills on the south side of the valley east of and near the mouth of Reche Canyon and extending northwest along the west bank of Lytle Creek. This ridge is the lower limit of the upper Santa Ana artesian belt. It also serves to

force to the surface the return waters from irrigation that are flowing or percolating westward above the clay cap. Six-sevenths of the water of Riverside is obtained from underground sources above this range of clay hills. This ridge was probably formed by the folding of the floor of the valley.

A somewhat similar condition is repeated south of Chino, at Rincon where Santa Ana River has cut its way through the lower Coast Range. At this point the underground waters from Cucamonga, San Antonio, and Temescal creeks as well as the return waters from irrigation near Pomona, Ontario, Corona, and Riverside are forced to the surface, creating wet lands and rendering a water supply available for Anaheim, Santa Ana, and Fullerton. Beyond these low narrows there is an open plain to the sea, and the Santa Ana makes no further reappearance, except in an artesian district below the 10-foot contour. A view of the river below Rincon is shown in Pl. V, *A*, and a view of the division box of the Santa Ana and Anaheim canals which divert water from the river below Rincon, in Pl. V, *B*.

This artesian and percolating water yields a very uniform flow. The development works near Colton and San Bernardino draw from the reservoir as a spigot draws from a tank. The flow is relatively uniform, and the tank is filled by winter floods and by seepage. The greater portion of the hydrostatic pressure is exhausted in overcoming the large amount of friction expended by the water in passing through the sand, and its flow comes largely under the law of hydraulics. The capping or uncapping of numerous wells in a neighborhood has little immediate effect on the flow of any well until the full discharge capacity of the underground conduit is approached. When that occurs the water in all of the wells is lowered and pumping must be resorted to. Pl. VI (*A* and *B*) shows a group of artesian wells of the Riverside Water Company near Colton, in the Santa Ana River bottoms. In the foreground of Pl. VI, *B*, is shown an aerating basin.

The velocity of underground flow is extremely difficult to comput It has been discussed at length by Professor King and Professor Slichter, of Madison, Wis.,[a] and by Prof. L. G. Carpenter, of Fo Collins, Colo.[b] A great deal depends upon the size of the particl composing the soil and the way in which they are mixed. Cobble coarse sand, and sandy soil mixed in equal parts is more impervio than any one of the materials singly. Water percolating und ground for long periods often establishes underground channels fro an eighth of an inch to 10 inches in diameter, then ceases to percola and begins to flow through them. These conditions tend to confus because most of the formulas that have been presented are based soil grains of distinct sizes.

[a] Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. II.

[b] Bulletin No. 33 of Colorado experiment station, Fort Collins, Colo.

A SANTA ANA RIVER BELOW RINCON.

B. DIVISION BOX OF SANTA ANA AND ANAHEIM CANALS BELOW RINCON.

A. ARTESIAN WELLS OF RIVERSIDE WATER COMPANY.

B. ARTESIAN WELLS AND AERATING BASIN OF RIVERSIDE WATER COMPANY.

The flat valley area above Colton comprises 132 square miles, and it is reasonable to estimate that 100 square miles of this consists of gravel deposits eroded from the mountains. These gravels are of unknown but great depths. Numerous wells have been put down to a depth of 900 feet, and the writer does not know of bed rock being encountered. If this gravel bed is considered to have an average depth of 300 feet and the voids or interstices therein are taken at 33 per cent, the aggregate storage capacity would be 6,400,000 acre-feet. It is believed to be greater instead of less than this amount. As the water plane is drawn down throughout this mass its capacity to absorb subsequent floods at its rim, where the mountain streams debouch, is increased. It is a great regulating reservoir, sufficient in capacity to carry the irrigation communities through cycles of dry years, to be recharged during those of copious rainfall. The observations of the elevation of this water plane will be of value in making comparisons at a later date to determine whether the present rate of withdrawal is permanently lowering it or if in wet years the rainfall is sufficient to recharge the reservoir and restore it to its former level. This subject is of vital interest to the irrigators of the valley. From data now available a continuous withdrawal of 140 second-feet is believed to be reasonably safe.

The water of Warm Creek and of the artesian wells of the Gage system has been analyzed by Prof. E. W. Hilgard, of the University of California, with the following results:

Analyses of waters from artesian wells of the Gage system and from Warm Creek.

[Composition in 10,000 parts.]

	Artesian wells.		Warm Creek at mill.		Artesian wells.		Warm Creek at mill.
	Group D, No. 5.	Group A, No. 2.			Group D, No. 5.	Group A, No. 2.	
	Per ct.	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*
Total residue	1.911	2.266	2.604	Calcium carbonate	1.017	1.212	0.702
Soluble part	.418	.418	1.119	Magnesium carbonate	.232	.249	.253
Sodium chloride (common salt)	.063	.091	.257	Silica	.244	.239	.324
Sodium sulphate (glauber salt)	.193	.313	.582	Summary, in grains per gallon:			
Sodium carbonate (soda)	.102	.021	.200	Total residue	11.16	13.23	15.21
Potassium sulphate	.060	.068	.080	Soluble part	2.44	2.84	6.53
Insoluble after evaporation	1.493	1.778	1.485	Insoluble after evaporation	8.72	10.38	9.67
Calcium sulphate	.....	.078	.146				

In total solids this water compares favorably with that of Los Angeles and Kern rivers, and is much purer than the water of the coast streams. It carries large quantities of potash salts, and not enough calcium carbonate to injure the well-drained lands of the Riverside mesa.

SMALL CANALS NEAR COLTON AND SAN BERNARDINO.*

DESCRIPTIONS.

Haws & Talmage ditch.—This ditch receives its supply from the rising water of Warm Creek, and is the first diversion on that stream between Harlem and Rabel Springs. It is a small earthen ditch, and takes water from the south side or left bank of the creek, and distributes it southwest of Harlem Springs. The diversion is by means of a dam. The ditch is three-fourths of a mile long. It is owned and maintained by local ranchers, and is entitled to 50 miners' inches (1 second foot) of water. Usually the ditch is cleaned each spring, or whenever it becomes so foul that some irrigator can not get as much water as he requires. The water is used for alfalfa and other dairy products. The cost of maintenance of ditches of this class is from 50 cents to $1 per acre per year. The supply is relatively constant. The ditch was built in 1857, separating its water right from that of the Rabel Dam ditch. During the years 1898 and 1899 this ditch was practically dry, the only water it received being that pumped from the Harlem swimming pool which is cleaned about twice a week. In June and August, 1899, and in March 1900 and 1901, the ditch was dry.

Rabel Dam ditch diverts its water by means of an earthen dam at lot 2, block 60 San Bernardino Rancho, on Warm Creek. It is the second ditch on that stream. As is the case with all of these rising waters, the supply is practically constant throughout the year. An agreement, made in October, 1895, between the Riverside Water Company and the owners of the ditch provided for the natural flow of water in Warm Creek at the head of the ditch to the amount of 250 miners' inches, and in the agreement it was stipulated that the Riverside Water Company should at its own expense build at the head of the ditch an iron weir embedded in cement foundation, to measure the water. This was done. The canal is an earthen ditch 4.2 miles in length, and has a capacity of 250 miners' inches (5.0 second feet). It takes its water from the south side of Warm Creek and carries it to the southwest of Harlem Springs, irrigating 400 acres of alfalfa, vegetables, and garden produce. It is owned and operated by local ranchers. It was built in 18[illegible] by the Mormon settlers, and is the oldest water right on Warm Creek. On June 20, 1898, it was discharging 5.37 second-feet. During the summer of 1899 the iron weir at the head of the ditch was removed by the owners of the ditch, with the consent of the Riverside Water Company. The upper part of the ditch was lowered by running it on a flatter gradient to the headworks, with the idea of diverting Warm Creek at a lower level. This plan increased the flow of water for a time but it soon dropped to less than the original flow.

Shay or Stout Dam ditch.—The headworks of this ditch are in the west half of lot 4, block 60, San Bernardino Rancho, 1 mile north and 3 miles east of the city of San Bernardino. The diversion is by means of an earthen dam. The supply is relatively constant. The canal is 1¼ miles in length; it runs west on the north side of the San Bernardino base line and Warm Creek, and irrigates those lands. The ditch is used the year round, and is cleaned twice a year. The cost of maintenance to consumers is less that $1 per acre per year. It served 210 acres in 18[illegible] and 150 acres in 1898. It was built in 1857, and ranks third in its order of water rights to Warm Creek. By a compromise made with the Riverside Water Company in 1895 this ditch is entitled to 112.5 miners' inches of water (2.25 second-feet) provided there is that amount in Warm Creek at the headworks. During the years 1899 and 1900, however, the supply fell considerably below that quantity.

McKenzie ditch.—The headworks, consisting of a wooden dam, are on Warm Creek, the center of lot 8, block 51, San Bernardino Rancho, 2 miles east of the city of San Bernardino. The supply is relatively constant. The ditch was bu[illegible]

*The writer is indebted to Mr. Kingsbury Sanborn for most of the data regarding the canals.

t irrigates lands immediately east of San Bernardino, between City and ›ks, and 85 acres on the south side of City Creek. The canal is about 1.3 ngth. It is an earthen ditch built in sandy loam, with a flat grade, and nd operated by local ranchers. It is said to lose 33 per cent of its vol- ›page. The owners claim all of the water of Warm Creek at the point n, but the Riverside Water Company claims that their right is limited to ıl capacity of the ditch, which was 100 miners' inches (2.0 second-feet). is still in litigation. It has lately been enlarged. Three hundred acres ınd gardens are irrigated. Cost of maintenance is prorated and amounts 0 cents per acre per year. On June 20, 1898, it was discharging 127 :hes (2.54 second-feet).

Daley ditch.—This ditch originally diverted its water from the lower ırm Creek, and the Agua Mansa, Juaramillo, and San Salvador canals : from Santa Ana River, southeast of Colton. The owners of these four cleaning them out each year, gradually enlarged their sections, to the of the Riverside Water Company, which company instituted suit em to restrict their diversion. To avoid a protracted lawsuit and oss of water by seepage in sandy channels, a compromise was arranged which the Riverside Water Company agreed to build and deliver to the these ditches a cement-lined canal, estimated to cost $30,000, which iver from this conduit, at certain stated points, the following amounts

Ditches to be supplied by cement-lined canal.

Name of ditch.	Original source of supply.	Water guaranteed.
		Miners' inches.
ey	Warm Creek	400
	Santa Ana River	50
	do	250
r	do	125
›oration (estimated)		25
		850

al was built by the Riverside Water Company at a cost of $37,281. All aining available from the sources of these canals belongs to that com- 1885 the Meeks & Daley Water Company was incorporated, with a ck of $78,000 divided into 780 shares. t› handle these combined waters. lworks of the new canal were located 1½ miles northeast of the town of l a half mile east of Bunker Hill. The headworks of the Meeks & Daley ist of a well-constructed brush dam across Warm Creek, which diverts to a weir at the head of the ditch. At the weir the ditch is 10 feet wide tom and 1½ feet deep, with side slopes of 1½ to 1, gradually contracting ıal size at station 28, which is 3 feet wide on the bottom, 5 feet wide top, and 2 feet deep. The sides are of rubble masonry, with a 3-inch ottom, and the whole inside is plastered with cement mortar a half inch e supply is from Warm Creek and is very constant in volume. Under ıct the Riverside Water Company made a saving of from 100 to 200 :hes (2 to 4 second-feet). The canal built by them is about 3½ miles It runs through the southern side of the town of Colton and around side of Slover Mountain, being on the north or right bank of Warm Santa Ana River. It is owned by a stock company of local ranchers, › of the stock carrying with it a water right to some certain piece of ıich it is appurtenant. The water is used largely for the irrigation of ts.

The Agua Mansa ditch is an extension of the Meeks & Daley ditch through the Agua Mansa and San Salvador districts. It is of the same construction as the Meeks & Daley ditch, but is smaller, being 2 feet on the bottom and from 1 foot to 1½ feet deep, according to the grade, with side slopes of ½ to 1. Very little of the original Agua Mansa land is now irrigated, as the irrigation on the mesa has converted the land into a bog hole, unfit for cultivation, and many shares of water have been sold to ranchers in West Riverside, who now own the controlling interest and are using the water on their lands.

Beam ditch derives its water from a cienaga tributary of Warm Creek in lot 14, block 43, San Bernardino Rancho. The ditch is about a mile in length. The water is diverted by means of a brush dam, and flows in a southwesterly direction, irrigating the land lying west of Warm Creek, in blocks 43 and 44 of the San Bernardino Rancho. The ditch has an apparent capacity of 45 miners' inches, and irrigates about 100 acres of land. On June 20, 1898, it was flowing 0.67 second-foot in the flume near the headworks.

Timber ditch.—This was one of the first canals constructed in San Bernardino Valley. It diverted its water from Santa Ana River near the center of sec. 8, T. 1 S., R. 3 W. The water rights of this canal were transferred by individual owners to the North and South Fork canals of Highlands and Redlands, and at the present time it is practically abandoned. The water was applied to the lands between the city of San Bernardino and Santa Ana River. It was entirely dry during the summers of 1898 and 1899. At its headworks there is a flume intake 4.3 feet wide and 2 feet deep, also a crib diversion dam. This ditch is described in the Nineteenth Annual Report of the United States Geological Survey, Part IV.

Logsdon & Farrell or Waterman ditch.—The Logsdon & Farrell ditch makes its diversion from the south side of City Creek, a mile east of the city of San Bernardino, by means of a flume 2 feet wide and 1 foot deep and a rough sheet-pile dam. The canal is three-fourths of a mile in length, and its water is used southeast of the city. About 80 acres of gardens are irrigated. On June 29, 1898, there was flowing in this ditch 36 miners' inches (0.72 second-foot) of water. This ditch is a combination of the Waterman, Logsdon-Farrell, and Brooks ditches.

Whitlock ditch.—This ditch takes its water from the north bank of City Creek 2 miles east of the business portion of the city of San Bernardino, and is about a half mile in length. At the place of measurement it is a flume 1.5 feet wide and 0.8 foot deep, and on June 29, 1898, it was discharging 12 miners' inches, or 0.24 second-foot. Its water is used to wash vegetables, and it is mingled with the waters of the McKenzie ditch and used on Chinese vegetable gardens.

Daley ditch.—This ditch diverts water three-fourths of a mile east of the business portion of the city of San Bernardino and about one-fourth of a mile east of the junction of Warm and City creeks, from the north side of the latter creek, crosses to the south side of that creek, and distributes its water on 40 acres of block 6 of the San Bernardino Rancho. It is about a half mile in length. The flume crossing City Creek is 1 foot wide and 1 foot deep. On June 29, 1898, it was carrying 31 miners' inches (0.62 second-foot).

McIntyre ditch.—This canal makes its diversion from the south or right bank of Lytle Creek, near the southwest corner of the city of San Bernardino, and receives its supply from the return water of that creek. It is approximately 1 mile in length, and distributes its water on the south side of Lytle Creek, between Colton avenue and Mount Vernon avenue. It is an eight-day ditch, and is owned by local ranchers, who maintain it for about 70 cents per acre per year. About 30 acres are irrigated for alfalfa. During the years 1898, 1899, 1900, and 1901 the ditch was dry.

Whiting ditch also derives its supply from the return water of Lytle Creek, and distributes it on the adjoining lands of D. G. Whiting, who owns the ditch. On June 27, 1898, it was carrying 15 miners' inches (0.30 second-foot). Twenty-five acres of pasture are irrigated.

Furguson water.—This is a 2½-miners' inch right in Ranchero ditch, which comes from Raynor Springs. The water is used around Bloomington.

Ward & Warren ditch.—This is one of the oldest ditches on Santa Ana River, and is the outgrowth of the Warren-Warner ditch, the Jansen ditch, and the waste water from the Hunt & Cooley ditch. The ditch originally took its water from Santa Ana River near the east end of the Southern Pacific Railway bridge, in lot 8, block 64, San Bernardino Rancho, but during the flood of 1892 the main channel of Santa Ana River was changed to a point about a half mile to the north, and the following spring the Ward & Warren ditch was extended to the new channel of the river. The water is now diverted by means of a rough sand and brush dam in the westerly part of lot 2, block 64, San Bernardino Rancho.

During the years 1888 and 1889 this ditch was considerably enlarged and the water spread over a greater area. The Riverside Water Company, which had been using the water of Santa Ana River for years, brought suit against the owners of the ditch, to restrain them from using all the water in Santa Ana River at their headworks, claiming that they were entitled to only the original capacity of the ditch.

The case came to trial February 26, 1890, the decision being that the owners of the ditch are entitled to the water flowing from Santa Ana River at the head of the Ward & Warren ditch to the extent of 309 miners' inches (6.18 second-feet), measured under a 4-inch pressure, the measurement to be made from the center of the orifice, and that the Riverside Water Company is the owner and entitled to the use of the remainder of the water flowing in Santa Ana River at the head of the Ward & Warren ditch. The court further decreed that the owners of the Ward & Warren ditch are entitled to have from the Rice & Thorne tracts (which are owned by the Riverside Water Company) on Santa Ana River water to the amount of 78.18 miners' inches (1.56 second-feet), measured under a 4-inch pressure from the center of the orifice, when necessary to make up the 309 miners' inches. This 78.18 miners' inches was the overflow from the fish pond of a cienaga located on their lands, the stream of which is one of the natural tributaries of Santa Ana River. This pond, owing to the dry season and the development of artesian water in that neighborhood, is now almost dry, and the 78.18 miners' inches delivered to the Ward & Warren ditch is now practically all artesian water. The line of the ditch is located through the dry and sandy bed of Santa Ana River and loses a large percentage of its water before reaching the first point of distribution. In June, 1898, this ditch was receiving from the Rice-Thorne canal 1.60 second-feet of water and from Santa Ana River 0.72 second-foot.

North Riverside or Jurupa canal.—The Jurupa canal, sometimes called the North Riverside, derives its water from different sources: (1) From a covered flume in the Santa Ana River bottom, in lot 3, block 88, San Bernardino Rancho, above Colton avenue crossing; (2) from surface development in two cienagas in lot 2, block 88, San Bernardino Rancho; and (3) from the Salazar water. The Salazar water was originally diverted from the bed of Santa Ana River.

The Riverside Water Company agreed, because of the priority of the Salazar right, to permit the water for this ditch, to the extent of 75 to 100 miners' inches (1.5 to 2 second-feet), to pass its headworks and be conveyed by a sandy river bed to the Salazar headworks. In order to prevent the loss by seepage and evaporation in the river bed, the Riverside Water Company now delivers into the Jurupa flume 75 miners' inches (1.5 second-feet), in consideration for which it diverts all of the water at the headworks of its canal. All of these developments occur east of the Colton avenue crossing of Santa Ana River. The ditch which is now called the Rubidoux ditch is generally known as the Jurupa ditch, and diverts its water from Santa Ana River just north of the point where the county line between Riverside and San Bernardino crosses the lands of the Rubidoux ranch. The ditch now known as the Jurupa, belonging to the North Riverside Land

and Water Company, diverts a portion of its water from an underground flow in the bed of Santa Ana River a short distance east of the Colton avenue bridg On July 1, 1898, the canal was flowing 7.11 second-feet at the Colton avenu crossing. This includes the 75 miners' inches (1.50 second-feet) of Salazar wate The main canal is 17 miles in length. The company owns the land upon whic the water is distributed, and claims the right to develop all the water avai able at its headworks. The first 350 miners' inches (7 second-feet) belo to settlers to whom the company had sold water and land. The Jurupa ditc carries 75 miners' inches from the Riverside Water Company's flume, and th water is known as the Salazar right. It is measured at the junction of the Rive side Water Company's flume with the North Riverside and Jurupa can Agua Mansa water enters the Jurupa canal from the Meeks & Daley ditch 1 mi southwest of Slover Mountain, and is carried by it to the San Salvador distri The Temescal tin mine syndicate has a run of 200 miners' inches (4 second-fe for twenty-four hours every eighth day through the Jurupa ditch. Ordinar the Jurupa ditch contains—

	Miners' inches.	Second-feet.
Agua Mansa water	350	(7.0)
Salazar water	75	(1.5)
Santa Ana River water	350	(7.0)
Total	775	(15.5)

The following measurements have been made:

	Miners' inches.	Second-feet.
July 1, 1898, Jurupa flume at Colton avenue	355	(7.11)
June 18, 1898, Jurupa flume below Agua Mansa junction, including Agua Mansa water	691	(13.83)
August 27, 1898, Jurupa flume at Colton avenue, below Agua Mansa junction, including Agua Mansa water	509	(10.18)

During the year 1897 the assessments to the owners of the Jurupa ditch amoun to $9.54 per miners' inch. They charge $3.27 per inch per year for carrying A Mansa and other water.

The canal is located around a rock hill immediately above the old upper ca of the Riverside Water Company and crosses the river in a flume on a tre 2,460 feet in length, shown in Pl. VII, *B*. Then for 2 miles the water is flu along a bluff on the north bank of the river, after which it passes through a t nel 4,000 feet long into an open ditch 3 miles long, and thence to the Jur mesa lands. The Jurupa Land and Water Company was incorporated in M 1888, with a capital stock of $3,500,000, divided into $100 shares.

Hunt & Cooley or Camp Carlton ditch.—This was originally one of the ol diversions on middle Santa Ana River. It was taken out in 1859, and had eral headings in the river, which were washed out by floods, until the fi one was made at about the point where the Gage canal started to divert its wa and it remained there until the year 1887, when the managers of the Gage ca agreed with the owners of the ditch to bore wells and develop for them 130 min inches of water, and to receive in return what they thought to be the right to the water flowing in Santa Ana River at the headworks of this ditch. This le a long and expensive lawsuit with the Riverside Water Company, who conten that the Gage canal was entitled to only an amount of water equal to the origi capacity of the canal, which was 200 miners' inches. It resulted, however, in courts allowing the Gage canal the right to 298.5 miners' inches of the flow Santa Ana River at the headworks of their canal.

A. FLOWING WELLS OF GAGE CANAL SYSTEM, VALLEY OF SANTA ANA RIVER.

B. FLUME AND INVERTED SIPHON OF JURUPA CANAL.

DISCHARGE MEASUREMENTS.[a]

Hawes & Talmage ditch.—On June 7, 1898, 0.84 second-foot was flowing in this ditch near the headworks. The area of the water section was 0.9 square foot, the surface velocity 1.33 feet per second. Measurements were made by floats. Coefficient 70 per cent.

September 14, 1898, all of the water in Warm Creek at the head of the ditch was passed through the waste gate; by weir it measured 0.43 second-foot. The weir was 4.6 feet long, the head 0.094 foot, two full contractions, velocity of approach less than 0.5 foot per second.

March 2, 1899, a weir was put in near the head of the ditch, and the discharge measured 0.28 second-foot; length of weir 1 foot, head 0.2 foot, velocity of approach less than 0.5 foot per second, two full contractions.

In June and August, 1899, and in March and on June 12, 1900, the ditch was dry.

Rabel Dam ditch.—September 14, 1898, at 2.10 p. m., this ditch was diverting 3.07 second-feet over the iron weir at the headworks, which was all of the water in Warm Creek at that point. The weir is 4 feet long, the head was 0.38 foot, two full contractions, velocity of approach less than 1 foot per second.

March 2, 1899, the ditch was discharging 2.36 second-feet at the head; length of weir 4 feet, head 0.31 foot, velocity of approach less than 1 foot per second, two full end contractions. This was all of the water in Warm Creek at the point of diversion.

June 16, 1899, at 1.45 p. m., this ditch was discharging 1.54 second-feet; head 0.24 foot, length of weir 4 feet, two full end contractions, velocity of approach less than 0.5 foot per second.

During the summer of 1899 the iron weir at the head of the ditch was removed by the owners of the ditch, with the consent of the Riverside Water Company. The upper part of the ditch was lowered by running on a flatter gradient to the headworks, with the idea of diverting Warm Creek at a lower level. This plan increased the flow of water for a time, but it soon dropped to less than the original flow.

August 25, 1899, the discharge measured 0.94 second-foot; the water area was 0.9 square foot, the surface velocity 1.5 feet per second.

March 15, 1900, the 4-foot iron weir was again in place; the discharge measured 0.54 second-foot, the head was 0.12 foot, and there was no perceptible velocity of approach.

June 12, 1900, at 12 m., the discharge measured 0.35 second-foot at the headworks weir; length of weir 4 feet, head 0.09 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

Shay or Stout Dam ditch.—On June 20, 1898, the volume in this canal measured 2.30 second-feet; length of weir 2 feet, head 0.502 foot, velocity of approach 0.7 foot per second, two end contractions.

September 14, 1898, at 1.55 p. m., the discharge over the same weir was 2.08 second-feet. Being at the end of the irrigating season the ditch had not been cleaned and was very foul. The tail water was higher than the crest of the weir by 0.193 foot, causing the weir to be submerged. Head 0.5 foot, two end contractions, velocity of approach less than 0.5 foot per second. Fteley and Stearns's formula was used.

March 2, 1899, the discharge over the same weir was 2.23 second-feet; head 0.5 foot, two end contractions, velocity of approach less than 0.5 foot per second.

June 16, 1899, at 2.10 p. m., the discharge was 1.13 second-feet. The ditch was again foul, and the weir was submerged 0.320 foot; head 0.406 foot, velocity of approach less than 1 foot per second.

[a] All measurements were made by Mr. Kingsbury Sanborn, of Riverside, except where stated to the contrary.

August 25, 1899, at 2.15 p. m., the discharge measured 0.9 second-foot, head 0.27 foot, two end contractions, velocity of approach less than 0.5 foot per second.

A few months previous to March 15, 1900, when a measurement was made, the owners of the Shay ditch relocated the ditch, starting from the headworks and taking it to higher grounds, which caused the water to back entirely over the weir, so that it became necessary to make a float measurement. The water area was 1.45 square feet, surface velocity 0.5 foot per second, discharge 0.507 second-foot, coefficient 70 per cent.

On June 19, 1900, at 1.10 p. m., the discharge was 0.4 second-foot about 200 feet below the dam across Warm Creek; sectional area 1.7 square feet, surface velocity 0.34 foot per second, coefficient 70 per cent.

McKenzie ditch.—On June 20, 1898, a float measurement was made. The area of the section was 2.90 square feet, surface velocity 1.25 feet per second, coefficient 70 per cent, discharge 2.54 second-feet.

September 12, 1898, at 2.30 p. m., the discharge a half mile below the headworks measured 2.08 second-feet. The sectional area was 5.2 square feet, the velocity of approach 0.64 foot per second, coefficient 70 per cent.

March 2, 1899, the discharge measured 9.4 second-feet at the same point as the last measurement; the sectional area was 4.9 square feet, surface velocity 2.77 feet per second, coefficient 70 per cent.

June 16, 1899, at 2.45 p. m., the discharge measured 3.86 second-feet about 150 feet below the headworks on Warm Creek; the sectional area was 1.9 square feet, surface velocity 2 feet per second, coefficient 70 per cent.

August 22, 1899, there was flowing in the ditch at the same point as the last measurement 2 second-feet; the sectional area was 4.1 square feet, the surface velocity 0.7 foot per second, coefficient 70 per cent.

March 16, 1900, the discharge measured 2.3 second-feet about 250 feet below the headworks on Warm Creek; the sectional area was 3.3 square feet, the surface velocity 1 foot per second, coefficient 70 per cent.

June 19, 1900, at 1.10 p. m., the discharge measured 1.57 second-feet about 150 feet below the headworks dam; the sectional area was 2.2 square feet, the surface velocity 1 foot per second, coefficient 70 per cent.

Meeks & Daley ditch.—Measured on June 20, 1898, the discharge at the headworks weir was 8.42 second-feet (421 miners' inches); length of weir 6 feet, head 0.525 foot, two end contractions, velocity of approach less than 0.5 foot per second.

Measured on March 2, 1899, at the headworks weir the discharge was 17 second-feet; length of weir 6 feet, head 0.917 foot, two end contractions, velocity of approach less than 1 foot per second.

June 26, 1899, the discharge at the headworks weir was 15.48 second-feet, the head 0.845 foot, two end contractions.

August 25, 1899, the discharge at the headworks weir was 10.45 second-feet, head 0.659 foot.

March 1, 1900, the weir was submerged 0.28 foot; the discharge was 13.94 second-feet; length of weir 6 feet, head 0.84 foot, velocity of approach less than 1 foot per second.

June 19, 1900, at 4 p. m., the discharge measured 13.78 second-feet at the headworks weir, which was submerged 0.415 foot; the velocity of approach was less than 1 foot per second, length of weir 6 feet, head 0.875 foot, two end contractions.

Logsdon & Farrell ditch.—Measured near headworks on June 29, 1898, by J. B. Lippincott and K. Sanborn. Area of section 0.878 square foot, mean velocity 0.824 foot per second, coefficient 80 per cent, discharge 0.72 second-foot.

In September, 1898, the discharge was 0.63 second-foot at the same place.

March 1, 1899, 1.61 second-feet of water was in the flume near the headworks. This ditch is flat, and it is impossible to put in a weir without losing a large percentage of the water, so that it became necessary to make float measurements. [illegible]*dth of the* flume is 2 feet, the depth of the water 0.7 foot, sectional area

1.41 square feet, surface velocity 1.43 feet per second, coefficient 80 per cent. The flume was in fair condition.

June 27, 1899, the discharge measured 1.15 second-feet at the same place; depth of water 0.71 foot, surface velocity 1 foot per second, sectional area 1.44 square feet, coefficient 80 per cent.

August 25, 1899, the discharge measured 0.54 second-foot in the flume near the headworks, which was in fair condition. The depth of water was 0.56 foot, surface velocity 0.6 foot per second, sectional area 1.12 square feet, coefficient 80 per cent.

March 15, 1900, the discharge measured 1.26 second-feet at the same place. There was a deposit of sand in the bottom of the flume, and the depth of water was as follows: Side 0.82 foot, center 0.86 foot, and opposite side of flume 0.84 foot. The surface velocity was 1 foot per second, coefficient 75 per cent.

June 23, 1900, the discharge measured 0.49 second-foot in the ditch near the headworks dam: sectional area 0.9 square foot, surface velocity 0.77 foot per second, coefficient 70 per cent.

Beam ditch.—Measured June 30, 1898, 300 feet below headworks, by floats. Area of section 1.08 square feet, mean velocity 0.63 foot per second, discharge 0.67 second-foot.

March 2, 1899, discharge measured 0.72 second-foot in the flume near the headworks. This ditch is very flat, and it is impossible to put in a weir and get satisfactory results; for that reason float measurement was made. The water area was 1.5 square feet, the surface velocity 0.6 foot per second. The flume was in fairly good condition. Coefficient 80 per cent.

June 27, 1899, measured in the same flume as the last measurement. Discharge 0.52 second-foot, width of flume 1.38 feet, depth of water 0.95 foot, surface velocity 0.5 foot per second, coefficient 80 per cent.

August 25, 1899, the discharge at the same place measured 0.4 second-foot. the depth of water was 0.84 foot, surface velocity 0.5 foot per second. Flume in fairly good condition. Coefficient 80 per cent.

March 15, 1900, the discharge measured 0. 68 second-foot, same place, same conditions. The depth of water was 0.62 foot, the surface velocity 1 foot per second, coefficient 80 per cent.

June 14, 1900, at 2 p. m., the discharge measured 0.5 second-foot at the same place; the sectional area was 1.14 square feet, the surface velocity 0.59 foot per second, coefficient 75 per cent.

Upper canal of Riverside Water Company.—On June 30, 1898, the discharge over the headworks weir (see Pl. IX) was 59.04 second-feet. There are three weirs, with end contractions, each 9¼ feet long. Head equals 0.677 foot, velocity of approach 1.12, 2.18, and 1.94 feet per second, respectively.

February 28, 1899, the discharge was 60.53 second-feet. the head 0.843 foot.

June 26, 1899, the discharge was 53.92 second-feet, the head 0.686 foot.

August 31, 1899, there were 52.04 second-feet of water flowing over the headworks weir, and the head was 0.67 foot.

March 21, 1900, there were 61.94 second-feet flowing. Head 0.755 foot.

June 23, 1900, at 3 p. m., the discharge at the headworks weir measured 52.94 second-feet; the head was 0.68 foot, average velocity of approach 0.77 foot per second, full contractions.

Lower canal of Riverside Water Company.—Meter measurement on June 17, 1898, at 4 p. m., as determined by Mr. F. H. Olmsted, was 9.27 second-feet.

June 18, 1898, at 10 a. m., Mr. Olmsted made a meter measurement and found a discharge of 11.27 second-feet.

June 27, 1898, there were 10.83 second-feet of water flowing in the flume just below the intake at Santa Ana River. The sectional area was 4.18 square feet, the velocity 3.24 feet per second, coefficient 80 per cent.

September 2, 1898, there were 7.7 second-feet of water flowing at the same place. The water area was 3.84 square feet, the velocity 2.5 feet per second, coefficient 80 per cent.

March 10, 1899, there were 16.20 second-feet flowing over the weir at the end of the flume. Length of weir 5 feet, head 1.01 feet, two full end contractions, velocity of approach less than 1 foot per second.

June 28, 1899, the discharge at the same place measured 9.09 second-feet, the water area was 3.63 square feet, the surface velocity 3.12 feet per second, coefficient 80 per cent.

September 1, 1899, the discharge in the flume measured 7.38 second-feet, the water area was 3.33 square feet, the surface velocity 2.77 feet per second, coefficient 80 per cent.

June 23, 1900, at 9.05 a. m., the discharge measured 7.16 second-feet in the flume; sectional area 3.4 square feet, surface velocity 2.63 feet per second, coefficient 80 per cent.

Gage canal.—On June 29, 1898, this canal was measured at its intake from Santa Ana River. The discharge was 1.16 second-feet over a weir 5 feet long, head 0.17 foot, velocity of approach 0.5 foot per second, no end contractions.

March 7, 1899, the discharge measured 0.72 second-foot, length of weir 5 feet, head 0.125 foot, velocity of approach less than 1 foot per second, no end contractions.

June 20, 1899, the discharge over the same weir measured 0.24 second-foot, head 0.06 foot.

August 25, 1899, the discharge over a weir 1 foot in length measured 0.64 second-foot, head 0.35 foot, velocity of approach less than 1 foot per second, two full contractions.

March 1, 1900, the discharge over the same weir measured 0.395 second-foot, head 0.25 foot.

June 7, 1900, the discharge measured 0.29 second-foot over same weir, head 0.3 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

Gage canal at Palm avenue weir.—June 30, 1898, Mr. K. Sanborn and Mr. J. B. Lippincott measured the flow over the weir, and obtained a discharge of 27.42 second-feet. The weir was 13.34 feet in length, with a head of 0.7 foot. There were two contractions. The velocity of approach was 1.4 feet per second. The level of the water below the weir was the same as the elevation of the crest, or knife edge.

September 21, 1898, there were 26.238 second-feet of water flowing over this weir. The head was 0.709 foot, the velocity of approach 1 foot per second, two full contractions.

March 7, 1899, the discharge over the weir measured 27.4 second-feet, head 0.73 foot, velocity of approach less than 1 foot per second.

June 26, 1899, the discharge measured 25.46 second-feet, head 0.69 foot.

August 15, 1899, the discharge measured 24.11 second-feet, head 0.67 foot.

March 21, 1900, the discharge measured 22.36 second-feet, head 0.639 foot.

June 7, 1900, the discharge measured 22.52 second-feet, head 0.64 foot, velocity of approach less than 1 foot per second.

Daley ditch.—Measured at 5.15 p. m. on June 29, 1898, by J. B. Lippincott and K. Sanborn. Discharge in flume across City Creek was 0.63 second-foot, water area 0.4 square foot, surface velocity 1.95 feet per second, coefficient 80 per cent.

September 12, 1898, at 11.30 a. m., the discharge measured 0.67 second-foot; water area 0.42 square foot, surface velocity 2 feet per second, coefficient 80 per cent.

March 1, 1899, the discharge measured 0.71 second-foot, the water area 0.354 square foot, surface velocity 2.5 feet per second, coefficient 80 per cent.

June 27, 1899, the discharge measured 0.51 second-foot, water area 0.32 square foot, surface velocity 2 feet per second, coefficient 80 per cent.

August 28, 1899, the discharge measured the same as on June 27, 1899.

March 15, 1900, the discharge measured 0.72 second-foot, water area 0.45 square foot, surface velocity 2 feet per second, coefficient 80 per cent.

June 23, 1900, at 12 m., the discharge measured 1.12 second-feet, the sectional area 0.28 square foot, the surface velocity 5 feet per second, coefficient 80 per cent.

McIntyre ditch.—June 12, 1898, at 4.25 p. m., the discharge measured 0.37 second-foot in flume near the head; the water area was 1.48 square feet, surface velocity 2.5 feet per second, coefficient 80 per cent.

September 14, 1898, the discharge measured 0.038 second-foot over a weir near the headworks, which was 0.5 foot in length; head 0.083 foot, no velocity of approach, two full end contractions.

March 1, 1899, the discharge measured 0.82 second-foot over a weir 1 foot in length; head 0.45 foot.

June 23, 1899, the discharge over the same weir measured 0.149 second-foot; head 0.13 foot.

August 26, 1899, there was no water flowing.

March 16, 1900, the discharge over the same weir measured 0.143 second-foot; head 0.126 foot.

June 12, 1900, the discharge over the same weir measured 0.01 second-foot; head 0.026 foot, two full contractions, velocity of approach less than 0.5 foot per second.

Whiting ditch.—June 27, 1898, the discharge measured 0.26 second-foot over a weir 1 foot in length near the headworks; head 0.19 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

September 14, 1898, the discharge measured 0.01 second-foot over a weir 0.5 foot in length; head 0.036 foot, velocity of approach less than 0.05 foot per second, two full end contractions.

March 1, 1899, the discharge measured 0.76 second-foot over a weir 1 foot in length: head 0.395 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

June 27, 1899, the discharge over the same weir measured 0.246 second-foot; head 0.182 foot.

August 26, 1899, the discharge over the same weir measured 0.009 second-foot; head 0.02 foot.

March 1, 1900, the discharge over the same weir measured 1.12 second-feet; head 0.522 foot.

June 12, 1900, the discharge measured 0.13 second-foot over the same weir; head 0.12 foot, velocity of approach less than 0.25 foot per second, two full end contractions.

Swamp ditch.—September 1, 1898, there were 1.02 second-feet flowing in flume to the Riverside Water Company's Rice-Thorne flume; the water area was 0.32 square foot, the surface velocity 3.5 feet per second, coefficient 80 per cent.

February 28, 1899, the discharge measured 0.85 second-foot over a weir at the first distributing box; length of weir 1 foot, head 0.427 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

June 20, 1899, the discharge over the same weir measured 0.77 second-foot; head 0.4 foot.

August 30, 1899, the discharge over the same weir measured 0.69 second-foot; head 0.37 foot.

March 21, 1900, the discharge over the same weir measured 0.7 second-foot; head 0.374 foot.

June 7, 1900, the discharge over the same weir measured 0.89 second-foot; head 0.44 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

Ranchero ditch.—September 22, 1898, at 1 p. m., the discharge measured 1.6 second-feet over a weir in the cement ditch on the Raynor ranch; length of we 4 feet, head 0.25 foot, velocity of approach less than 0.5 foot per second, two fu end contractions.

March 13, 1899, the discharge measured the same over the same weir.

June 23, 1899, at 4.30 p. m., the discharge over the same weir measured 1 second foot; head 0.18 foot.

August 26, 1899, the discharge over the same weir measured 0.41 second-foo head 0.1 foot.

March 17, 1900, the discharge over the same weir measured 0.24 second-foo head 0.07 foot.

June 12, 1900, the discharge measured 0.55 second-foot in the ditch; section area 0.74 square foot, surface velocity 1 foot per second, coefficient 75 per cent.

Ward & Warren ditch.—In June, 1898, this ditch was receiving from the Rio Thorne canal 1.60 second-feet of water and from the river 0.72 second-foot.

March 10, 1899, there were 3.09 second-feet flowing over a weir 3.33 feet length near the head of the ditch; head 0.434 foot, velocity of approach less tha 0.5 foot per second, two full end contractions.

June 20, 1899, the discharge measured 0.615 second-foot over a weir 1 foot length near the headworks; head 0.34 foot, velocity of approach less than 0.5 fo per second, two full end contractions.

August 30, 1899, the discharge measured 1.56 second-feet over a weir 2 feet length near the headworks; head 0.38 foot, velocity of approach less than 0.5 fo per second, two full end contractions.

March 19, 1900, the discharge measured 2.55 second-feet over a weir 3 feet length at the head of the ditch; head 0.41 foot, velocity of approach less than 0 foot per second, two full end contractions.

June 23, 1900, the discharge measured 1.7 second-feet in the ditch just belo the dam across Santa Ana River; sectional area 1.95 square feet, surface velocit 1.25 feet per second, coefficient 70 per cent.

Mill flume of Riverside Water Company.—June 15, 1898, there were 3.12 secon feet flowing at the end of the flume near the old Colton mill; water area 1.7 square feet, surface velocity 2.22 feet per second, coefficient 80 per cent.

September 12, 1898, at 3.35 p. m., there were 3.36 second-feet at the same plac water area 1.68 square feet, surface velocity 2.5 feet per second.

February 28, 1899, there were 5.3 second-feet at the same place; water ar 2.208 square feet, surface velocity 3 feet per second, coefficient 80 per cent.

June 26, 1899, the discharge measured 7.29 second-feet at the same place; wat area 3.04 square feet, surface velocity 3 feet per second, coefficient 80 per cent.

August 30, 1899, the discharge measured 2.56 second-feet at the same plac water area 1.6 square feet, surface velocity 2 feet per second, coefficient 80 per cer

March 9, 1900, the discharge measured 2.67 second-feet; water area 1.52 squa feet, surface velocity 2.2 feet per second, coefficient 80 per cent.

June 7, 1900, the discharge measured 2.17 second-feet; sectional area 1.36 squa feet, surface velocity 2 feet per second, coefficient 80 per cent.

Colton mill pump of Riverside Water Company.—June 15, 1898, there were 1. second-feet flowing over the weir at the old Colton mill; length of weir 4.015 fe head 0.276 foot, no end contractions, velocity of approach less than 1 foot p second.

September 1, 1898, there were 2.04 second-feet flowing over the same weir; he 0.286 foot.

June 26, 1899, 1.77 second-feet were flowing over the weir; head 0.26 foot.

August 31, 1899, 1.67 second-feet were flowing over the weir; head 0.25 foot.

June 7, 1900, the discharge over the weir measured 1.88 second-feet; head 0. foot, velocity of approach less than 1 foot per second, no end contractions.

amp Carlton ditch.—June 30, 1898, at 4.30 p. m., 0.61 second-foot was flowing r the weir at the Waterman avenue crossing; length of weir 3.33 feet, head 6 foot, velocity of approach less than 0.5 foot per second, two full end conctions.

eptember 12, 1898, at 9.30 a. m., there were 1.2 second-feet flowing over the e weir; head 0.229 foot.

larch 7, 1899, there were 2.13 second-feet flowing over the weir; head 0.333 foot.

une 20, 1899, 1.62 second-feet were flowing over the weir; head 0.28 foot.

ugust 27, 1899, 1.02 second-feet were flowing over the weir; head 0.25 foot.

larch 21, 1900, 2.55 second-feet were flowing over the weir; head 0.38 foot.

une 7, 1900, the discharge over the weir measured 2.6 second-feet, head 0.385 t, velocity of approach less than 1 foot per second, two full end contractions.

ast Riverside irrigation district.—It is stated that on June 10, 1898, 4.4 second-t were being pumped for this district at the head of the Vivienda pipe line.

eptember 17, 1898, at 4 p. m., measurement showed that 4.43 second-feet were ring over a weir 3.33 feet in length at the reservoir at the head of the Vivi-a pipe line, which runs to East Riverside. Head 0.55 foot, two full end conctions, velocity of approach less than 1 foot per second.

larch 13, 1899, 4.25 second-feet were flowing over the same weir; head 0.54 foot.

une 23, 1899, at 4 p. m., there were 2.08 second-feet flowing over the same weir; d 0.33 foot.

larch 1, 1900, there were 6.59 second-feet flowing over a weir 4.16 feet long in tunnel pipe line; head 0.6 foot, no velocity of approach, two full contractions.

une 12, 1900, the discharge over the foregoing weir measured 5.38 second-feet; d 0.542 foot, two full end contractions, velocity of approach less than 1 foot r second.

olton Terrace Water Company.—June 30, 1898, 1.97 second-feet were flowing er a weir 2 feet in length at Reservoir Hill; head 0.456 foot.

eptember 22, 1898, 1.61 second-feet were flowing over a weir at the head of the e line above First street in San Bernardino; head 0.3 foot, length of weir 3 feet.

March 13, 1899, 1.69 second-feet were flowing over the same weir; head 0.31 foot.

une 26, 1899, 1.3 second-feet were flowing over the same weir; head 0.26 foot.

ugust 26, 1899, the discharge measured the same as on June 26.

March 17, 1900, the discharge over the same weir measured 1.69 second-feet; head 1 foot.

une 12, 1900, the discharge over the same weir measured 1.54 second-feet; head 92 foot, velocity of approach less than 1 foot per second, two end contractions.

ity of Colton pumping plants.—June 26, 1899, 2.09 second-feet were flowing r a weir 4.17 feet in length at the head of the pipe line of the First street reser-r in San Bernardino; crest of weir 18 inches wide, head 0.29 foot.

ugust 26, 1899, 1.52 second-feet were flowing over the same weir.

ugust 26, 1899, the pumping plant west of Mount Vernon avenue was dis-rging 2.37 second-feet over a weir 2 feet long in the pipe line; head 0.52 foot, full contractions, velocity of approach less than 0.5 foot per second.

larch 17, 1900, the First street pumps were discharging 2.57 second-feet over a ir 4.15 feet long, crest 18 inches wide, head 0.33 foot, two full contractions, ocity of approach less than 0.5 foot per second.

une 12, 1900, the discharge of the two pumping plants measured 3.21 second-feet. e First street pump was discharging 1.23 second-feet over a weir 4.15 feet long the head of the pipe line; head 0.23 foot, velocity of approach less than 0.5 foot per ond, two full contractions. The Mount Vernon avenue pumps were discharging 8 second-feet over a weir 2 feet long in the reservoir; head 0.46 foot, two end con-ctions, velocity of approach less than 0.5 foot per second.

Whitlock ditch.—June 29, 1898, at 5 p. m., the discharge measured 0.34 second-t in the flume on Styles street across the McKenzie ditch; the water area was 5 square feet, surface velocity 1.6 feet per second, coefficient 80 per cent.

October 6, 1898, the discharge in the flume measured 0.38 second-foot, water ar
0.338 square foot, velocity of approach 1.42 feet per second, coefficient 80 per ce
March 1, 1899, the discharge in the flume measured 0.47 second-foot, water ar
0.59 square foot, velocity of approach 1 foot per second, coefficient 80 per cent.
June 27, 1899, the discharge in the flume measured 0.277 second-foot, water ar
0.6 square foot, velocity of approach 0.66 foot per second, coefficient 80 per cent
August 28, 1899, the discharge in the flume measured 0.094 second-foot, wa
area 0.147 square foot, surface velocity 0.8 foot per second.
March 15, 1900, the discharge in the same flume measured 0.232 second-fo
water area 0.145 square foot, surface velocity 1 foot per second.
June 23, 1900, the ditch at this point was dry.

Bloomington flume.—September 17, 1898, at 4.00 p. m., the Bloomington flu
was discharging 5.49 second-feet of water over a weir 2 feet in length at the up
end of the flume. That weir was submerged 0.41 foot; the head was 0.96 fo
velocity of approach less than 0.5 foot per second, two end contractions.
June 23, 1899, 5.930 second-feet were flowing over the same weir. The weir w
submerged 0.19 foot, the head was 0.95 foot, velocity of approach 2 feet per seco
two end contractions.
August 26, 1899, 3.05 second-feet were flowing over the same weir, which w
not submerged. The head was 0.62 foot.
March 16, 1900, the weir at the upper end of the flume was found to be destroy
3.8 second-feet were measured by floats at the lower end of the flume; the wa
area was 3.05 square feet, surface velocity 1.66 feet per second, coefficient 80
cent.
June 12, 1900, the discharge near the end of the flume measured 3.68 second-f
sectional area 3.93 square feet, surface velocity 1.25 feet per second, coefficien
per cent.

Johnson & Hubbard pumping plant.—March 16, 1900, 1.26 second-feet w
flowing in the flume at the lower end of the pipe line just east of Colton.
water area 1.1 square feet, surface velocity 1.43 feet per second, coefficien
per cent.

Comparative amounts of water, in second-feet, flowing in canals above Colto

Name of ditch.	June, 1898.	Sept., 1898.	Mar., 1899.	June, 1899.	Aug., 1899.	Mar., 1900.	June, 1900.	Se 19
Haws & Talmage	0.84	0.00	0.28	0.00	0.00	0.00	0.00	
Rabel Dam	5.37	3.07	2.36	1.54	.94	.54	.35	
Shay or Stout Dam	2.30	2.08	2.23	1.13	.90	.507	.40	
McKenzie	2.54	2.08	9.40	3.86	2.00	2.30	1.57	
Meeks & Daley	8.42	[b]17.00	17.00	15.48	10.45	13.94	13.78	1
Beam	.67	[b].65	.72	.52	.40	.68	.50	
Riverside Water Co., upper canal[a]	59.04	61.34	60.53	53.92	52.04	61.94	52.94	6
Timber	.00	.00	.00	.00	.00	.00	.00	
Gage canal, Santa Ana River	1.16	1.16	.72	.24	.64	.395	.29	
Gage canal, Palm avenue	[c]26.26	[c]25.07	[c]26.68	[c]25.22	[c]23.47	[c]21.96	[c]22.23	[c]
Logsdon & Farrel	.72	.63	1.61	1.15	.54	1.26	.49	
Whitlock	.34	.38	.47	.28	.094	.23	.00	
Daley	.63	.67	.71	.51	.51	.72	1.12	
McIntyre	.37	.038	.82	.15	.00	.14	.01	
Whiting	.26	.01	.76	.246	.01	1.12	.13	
Swamp	1.00	1.02	.85	.77	.69	.70	.89	
Ranchero	[b]1.75	1.64	1.64	1.00	.41	.24	.55	
Ward & Warren	2.32	[b]2.32	3.09	.615	1.56	2.55	1.70	
Mill flume, Riverside Water Co	3.12	3.36	5.30	7.29	2.56	2.67	2.17	
Mill pump, Riverside Water Co	1.94	2.04	[d]	1.77	1.67	[d]	1.88	
Camp Carlton	.61	1.20	2.13	1.62	1.02	2.55	2.60	
East Riverside	4.40	4.43	4.25	2.08	2.00	6.59	5.38	
Colton Terrace Water Co	1.97	1.61	1.69	1.30	1.30	1.69	1.54	
City of Colton	6.82	7.40	3.20	5.49	3.89	4.94	3.21	
Bloomington flume	5.26	5.49	[d]	5.93	3.05	3.80	3.68	
Total	138.11	144.69	146.44	132.11	110.14	131.46	117.41	1

[a] Above Slover Mountain. [b] Interpolated. [c] River water not included. [d] Pumps not

ater, natural flow in second-feet, compared with developed water in San Bernardino Valley above Colton.

of ditch.	June, 1898.		September, 1898.		March, 1899.		June, 1899.	
	Developed.	Natural.	Developed.	Natural.	Developed.	Natural.	Developed.	Natural.
lmage		0.84		0.00		0.28		0.00
		5.37		3.07		2.36		1.54
ut Dam		2.30		2.08		2.23		1.13
		2.54		2.08		9.40		3.86
		.67		.65		.72		.52
Water Co., up-	18.00	41.04	17.54	43.80	18.04	42.49	17.50	36.42
l, Santa Ana		1.16		1.16		.72		.24
, Palm avenue	26.26		25.07		26.68		25.22	
Farrell		.72		.63		1.61		1.15
		.34		.38		.47		.28
		.63		.67		.71		.51
		.37		.038		.82		.15
		.26		.010		.76		.246
		1.00		1.020		.85		.77
		[a]1.75		1.640		1.64		1.00
arren	1.60	.72	1.60	.720	1.60	1.49	.615	
of Riverside		3.12		3.360		5.30		7.29
of Riverside	1.94		2.04		Not run.		1.77	
on ditch	.61		1.20		2.13		1.62	
side district, or Highland Wa-	4.40		4.43		4.25		2.08	
race Water Co.	1.97		1.61		1.69		1.30	
lton pumping	6.82		7.40		3.20		5.49	
n flume	5.26		5.49		.00		5.93	
aley ditch		8.42		[a]17.00		17.00		15.48
	66.86	71.25	66.38	78.31	57.59	88.85	61.525	70.59

e of ditch.	August, 1899.		March, 1900.		June, 1900.		September, 1900.	
	Developed.	Natural.	Developed.	Natural.	Developed.	Natural.	Developed.	Natural.
lmage		0.00		0.000	0.00	0.00		0.00
		.94		.540		.35		.07
ut Dam		.90		.507		.40		.16
		2.00		2.300		1.57		1.69
		.40		.680		.50		.33
Water Co., up-	27.50	24.54	24.54	37.40	32.36	20.58	27.00	34.02
al, Santa Ana		.64		.395		.29		.17
, Palm avenue	23.47		21.96		22.23		27.85	
Farrell		.54		1.26		.49		.20
		.09		.23		.00		.00
		.51		.72		1.12		.54
		.00		.14		.01		.00
		.01		1.12		.13		.00
		.69		.70		.89		.86
		.41		.24		.55	.80	.53
arren	1.56		1.60	.95	1.60	.10	.53	
of Riverside		2.56		2.67		2.17		.94
of Riverside	1.67			Not run.	1.88		1.52	
ton ditch	1.02		2.55		2.60		1.67	
side district, or Highland Wa-	2.00		6.59		5.38		3.70	
race Water Co.	1.30		1.69		1.54		1.53	
lton pumping	3.89		4.94		3.21		3.54	
n flume	3.05		3.80		3.68		3.28	
aley ditch		10.45		13.94		13.78		14.68
	65.46	44.68	67.67	63.79	74.48	42.93	71.42	54.18

[a] Interpolated.

From the two preceding tables it will be noted that despite severe droughts which existed from 1898 to 1900, inclusive, the output of water from the gravel beds above Colton has but slightly diminished, the total being 144.69 second-feet in September, 1898, as compared with 125.61 second-feet in September, 1900. The amount of developed water in September, 1898, was 66.38 second-feet and in September, 1900, 71.42 second-feet, while the natural return water between the same dates decreased from 78.31 second-feet to 54.18 second-feet. During this period much development work was done, and while these new supplies do not mean an absolute addition to the output from the district, the fact that the total supply was maintained notwithstanding the drought is a decided achievement.

The most important question in considering this underground water supply is the rate at which the gravel beds will be recharged during wet years. This underground reservoir is of such magnitude, however, that it will require a term of years to demonstrate what these conditions are. Certainly more water can not be permanently pumped from a reservoir than its mean inflow. During this investigation an effort has been made to determine the elevation of the water plane throughout the valley above Colton, as shown on Pl. I. During the last four years the plane of saturation has been lowered. After a cycle of rainy years observations of these same wells should be taken to determine what the rise, if any, in the water plane has been. Not until this has been done will it be possible to state whether the supply is of a permanent nature. The data now at hand, though meager, indicate that 140 second-feet can with safety be continuously withdrawn, but this amount should not be greatly increased.

WELLS.

There are a large number of artesian wells near San Bernardino and Colton, in the basins of Santa Ana River, Lytle Creek, and Warm Creek. On page 530 of Physical Data and Statistics of California, published by the State engineering department in 1886, is given a list of 408 artesian wells above Colton, 208 of which were measured and found to be discharging 20.11 second-feet. Nearly all of these wells must have been near San Bernardino and Colton, and all of them must have been in San Bernardino Valley. In 1898 the wells in Santa Ana River Basin proper that supply irrigation water were all flowing wells. In the basin of Lytle Creek the wells are more numerous, and are owned either by individuals or by small corporations. In the town of San Bernardino many artesian wells have been bored for domestic purposes during the last twenty years, which when properly capped furnished water under pressure to many houses. These wells are from 200 to 400 feet deep, and all are driven through layers

of clay and gravel. They cost (in 1898), cased, from $1 per lineal foot for 4-inch wells to $2 per lineal foot for 10-inch wells. Some of them furnished as much as 50 miners' inches of water; many of the smaller wells flowed only 3 to 5 miners' inches. During the last four years many of these wells in the city of San Bernardino have ceased to flow, and the discharge of all of them has greatly decreased. These wells afford a very cheap water supply in a locality where the large irrigation companies charge from 5 to 20 cents for a run of 1 miners' inch for twenty-four hours. The area of artesian lands in this basin was 32 square miles in 1897 and 15 square miles in 1900. The irrigation companies have purchased these water-bearing lands. About fifty wells have been sunk in the Lytle Creek Basin. The prices at which the lands are sold vary widely. In August, 1888, the Riverside Water Company paid $25,000 for 40 acres of artesian land in the Warm Creek bottoms. In 1898 the same company bought the water right to 72 acres of excellent artesian lands in the Warm Creek Basin for $50 an acre. The latter price has also been paid in several localities northwest of San Bernardino, between the Lytle Creek Wash and the mesa to the west, which seems to be an extension of the Bunker Hill dike. Pumping plants have been placed in many of the wells, and the supply has thus been increased. The result has been to very largely exhaust the small domestic wells in the city of San Bernardino, and it would now appear that it has become a contest between the owners of the pumping plants as to which shall control the water. It probably is largely a question of pumping out an underground reservoir, and the man who taps it lowest down and has the strongest pump will get the most water. The results of a series of interesting experiments made by Prof. E. W. Hilgard on the wells at the head of the Gage system are given under the description of the water supply of that system. These experiments show that in April, 1889, capping and uncapping 27 adjoining flowing wells did not produce an immediate effect upon the surrounding wells.

The table on pages 84 and 85, showing the effect of opening and closing neighboring artesian wells of the Gage canal system, is also of interest in considering this matter. Observations of 55 wells were made in October, 1892, and while the volume of water increased as more wells were sunk, the aggregate flow is not so great, by 52 per cent, as the sum of the flow of the individual wells when all of the wells except one were closed.

The question whether the water supply in the aggregate can permanently be increased by digging larger wells and pumping is of course a vital one in this connection. An artesian basin is practically an underground reservoir. In this case it is probably refilled during wet years, principally by the winter floods from the surrounding mountain drainage basins and from the return water from irrigation. When the reservoir is filled the basin runs over at its rim and permits

larger surface flow. The wells tapping this basin at its lowest depression probably occupy the most favored positions, and those at the upper rim the poorest positions. All draw from the same source, and it is exceedingly difficult to tell which wells are responsible for the draining of those that have failed. It is claimed by the owners of the newer pumping plants that the failure of the wells that ceased to flow in 1898 is due to the series of dry years that preceded.

During the winter of 1897–98 there were very few floods, and even the normal winter flow of the streams was diverted for irrigation purposes. The same condition prevailed in the winters of 1898–99 and 1899–1900. The points of diversion on some of the surrounding streams have been moved higher up into the canyons and tunnels run under the stream beds to bed rock, which tends to decrease the supply of artesian water. While the wells near San Bernardino have failed and the wells in the Lytle Creek Basin have fallen from 19.12 second-feet in June to 13.94 second-feet in September, those in the lower central portion of the main valley have held their own. There is apparently no redress at law for those whose wells have failed, because it is difficult to show any direct stream relation between given groups, and at present the law does not take cognizance of so complex conditions.

The more an artesian basin is drawn upon the greater will be its storage capacity in unfilled voids during the following season; consequently it is possible that the total output from this basin may be permanently increased by tapping it more extensively in the lower levels. As a water supply is controlled absolutely by its minimum production, and as many of the artesian wells about San Bernardino failed during the summer of 1898, it is clear that the limit of artesian supply near the 1,100-foot contour has been reached. The limit of maximum available supply entering the artesian reservoir is governed by the area of the intake, the velocity of the entering water through the intake, and the length of time during which the entering water is available. These conditions are manifestly difficult of determination.

The large number and the great capacity of wells that have been bored in the lower regions of the artesian belt have so nearly approached the carrying capacity of the gravel and have so diminished the pressure at the lower wells that it is difficult to obtain a definite idea of the elevation at which water may be found in the upper regions of the artesian belt. A distinct grade is very noticeable in the crest of all wells when their pressure is considered. The flowing of water from these wells is changed from a condition of hydrostatics to one of hydraulics. It is of interest to note that when a well has an even flow over its casing, so that the height of rising water in the center of the well above the casing can be accurately measured, this height may be considered as the head on a weir, the length being

cumference of the pipe, end contractions being eliminated. obable error in this computation ordinarily will not exceed 4 nt.

of the wells in San Bernardino Valley in the Redlands and San rdino quadrangles, irrespective of their size or producing ties, were visited by the representatives of the Geological Sur- uring the summer of 1900. The 412 wells in the Redlands ngle were inspected by Mr. Louis Mesmer, of Los Angeles, and the 478 wells in the San Bernardino quadrangle were ted by Mr. C. J. Roney, observer. The results of their obser- s are contained in Part II of this report—Water-Supply and tion Paper No. 60.

esian wells of the Riverside Water Company.—During the last n years the Riverside Water Company has sunk 70 artesian n the Warm Creek Basin east of Colton and San Bernardino, ng in depth from 60 feet to 590 feet and in diameter from 6 inches nches. The largest well developed by the company previous to as in the bottom land of Santa Ana River, in lot 2, block 54, ernardino Rancho, about 2 miles east of the town of Colton. In ring of 1898 the managers of the Riverside Water Company d to increase this development by sinking numerous shallow 3 or 9 inches in diameter about 300 feet apart, and close enough harge their waters directly into the company's main conduit lead- Warm Creek. For this purpose two hand rigs were procured 3 wells were sunk, at an average cost of $1.75 per foot, the being an increase of 282 miners' inches (5.64 second-feet). wells were bored through alternate layers of sand and clay to -bearing gravel and bowlders by means of derricks and sand s.

total output of this tract, as measured June 30, 1898, was 554 s' inches (11.09 second-feet), 79 miners' inches (1.58 second- f which goes to the Ward & Warren ditch, the remaining 445 s' inches (9.51 second-feet) being delivered into Warm Creek bove the Riverside Water Company's upper canal diversion.

of the largest wells was sunk on the south side of Warm Creek 11, block 51, San Bernardino Rancho. It was commenced in ry, 1898, and was completed in February, 1898, the total cost $1,100. It is 590 feet deep, has a 10-inch casing of No. 10 iron, G. The water all comes from the bottom, and when com- the well flowed 120 miners' inches (2.4 second-feet). During mmer of 1898 a basin was placed around this well and con- l by a pipe to the main channel of Warm Creek. Twelve feet e was cut off from the top of the well to make it correspond he bed of Warm Creek. This increased the flow to 150 miners' (3.0 second-feet). The cost of water from this well was $7.33 per s' inch. There are seven wells on this tract, the aggregate flow

of which in August, 1898, was 340 miners' inches (6.8 second-feet). This water is carried in a vitrified clay pipe direct to the natural channel of Warm Creek, with whose waters it mingles, and on its course toward Riverside is allowed to pass through the various head gates of the irrigating ditches and is not deducted from the other stream measured at the Riverside Water Company's upper canal.

During the months of March and April, 1900, the Riverside Water Company sunk three wells, to an average depth of 552 feet, in block 44 of the San Bernardino Rancho. The water all comes from the extreme bottom of these wells. The pipes are 10 inches in diameter, of No. 12 iron, B.W.G. On May 19, 1900, the total flow of these three wells was 420 miners' inches (8.40 second-feet).

Martius well.—The Martius well, at Tippecanoe station, on the Riverside Motor Railroad, may be taken as a type of numerous pumped dug wells. It was excavated in 1893, is 20 feet deep and 12 feet in diameter. The wall is of dried brick laid on a wooden toe of crib work. Mr. Martius says that at first he used a steam engine to run the pump, but the cost was $3 for a day of ten hours. He now (1900) uses a 9-horsepower Webber gasoline engine, and the cost of pumping is $1.30 a day, or at the rate of 1.44 cents per horsepower per hour. A centrifugal pump is used, and 15 miners' inches (0.30 second-foot) of water are raised. This water is used for irrigation and street sprinkling. Ordinarily the cost of gasoline for power is about 33 per cent less than this amount.

PUMPING PLANTS.

One feature of special interest in the pumping plants in this valley is the use of electric motors for developing power. The mountain streams enter the valley on very heavy grades, and when diverted from their canyons into canals they obtain as much as 400 or 500 feet head in 4 or 5 miles length of conduit. The water is then dropped through large steel pressure pipes to nozzles which play on impulse water wheels of the Pelton, Knight, or Tuthill make.[a] These wheels have velocities so high that they can be coupled on the same shaft with the dynamos, thus eliminating loss by gearing. By means of transformers the voltage of the current to be transmitted is "stepped up" to from 20,000 to 40,000 volts, i. e., it is driven over the transmission line under very heavy pressure to the point where it is intended to be used. It is then "stepped down" to a low voltage for the motor which drives the pump. The 3-phase motor is the machine usually employed for this work. Numerous plants of this class have been in service in this locality for the last two years. They give little or no trouble, and are easily started under a load. One attendant can watch three or four of these plants when they are situated within distances of

[a] *For description of some of these power plants, see Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. IV.*

m a half to a fourth of a mile of one another. The 20-horsepower tor and the centrifugal pump is the most popular plant. The motor pherical in shape and only 4 feet in diameter. The amount of cur- t used for power is metered and paid for at meter rates. Single or hase motors have been tried for this work, but difficulty is found in rting them under a load. A secondary small machine called an xciter" has been used in starting them, but even then trouble is erienced. The method of obtaining power by the simple turning a switch, without the usual accompaniments of dirt and heat and h the little attendance that is required by a plant of this character, deal. It is a great improvement over the gas engine. Motors run- g horizontally, attached to the vertical shaft of the centrifugal mp, are now (1900) made, and give increased efficiency.

Descriptions of the pumping plants located east of Mount Vernon nue, San Bernardino, in the Lytle Creek bottom, are given below. s difficult to determine the volume of water pumped, as the pumps not run with uniform speed and usually discharge into pipe lines. e statements of owners as to volumes discharged have usually been epted, and while the amounts they give are probably somewhat in ess of the average flow, this will tend to compensate for a number minor flowing wells or windmill plants not visited or considered in s connection.

East Riverside Pumping Company, Raynor ranch.—In June, 1898, East Riverside Pumping Company was using at one of its wells a neral Electric 20-horsepower 3-phase motor under 550 volts pres- e. The power is measured by meter and costs (1898) 1 cent per r per horsepower for 20-hour days, or $6 a month. The power is nished by the Redlands Electric Light and Power Company and is eloped at the drop in the Mill Creek Canyon. In 1898 the electric or was consuming 16 horsepower and was lifting 85 miners' inches ater (1.7 second-feet) 28 feet high with a Byron-Jackson No. 6 trifugal pump discharging through a 6-inch pipe. The total out- from the plant of this company is 221 miners' inches (4.43 second-), as determined by weir measurement in September, 1898. The er is carried through the Vivienda pipe line to the East Riverside gation district.

City of Colton pumping plant.—The pumping plant of the city of ton furnishes water for irrigation and domestic use at and near t city. Two of the wells (Nos. 2 and 3) are located on what is wn as the Barnhill and Lamb tract, block 25, San Bernardino nch. The third well is on the south line of First street. All are he Lytle Creek Basin. These wells are locally known by numbers. Well No. 1 has a General Electric 20-horsepower 3-phase motor lying 14 horsepower in running a No. 6 Byron-Jackson vertical trifugal pump, and on June 27, 1898, it was lifting 121 miners' hes (2.42 second-feet) 35 feet high per day of 20 hours, which is

equivalent to 101 miners' inches (2.02 second-feet) for a 24-hour day. This is a cased well.

Well No. 2 is a 10-inch cased well. A General Electric 20-horsepower 3-phase motor of 550 volts capacity is running a No. 10 Byron-Jackson horizontal centrifugal pump, and in June, 1898, was said to be lifting 60 miners' inches (1.2 second-feet) of water 34 feet high per day of 20 hours, equivalent to 50 miners' inches (1 second-foot) for a 24-hour day. On September 22, 1898, this plant was furnishing 31 miners' inches (0.62 second-foot), weir measurement.

Well No. 3 is a 10-inch cased well on the Lamb tract. A 10-horsepower 3-phase electric motor with a capacity of 550 volts is running a Byron-Jackson horizontal centrifugal pump which on June 27, 1898, was raising 50 miners' inches (1 second-foot) of water 35 feet high per day of 20 hours, equivalent to 42 miners' inches (0.83 second-foot) for a 24-hour day. This plant is running with remarkable smoothness, there being no jar and scarcely any appreciable sound from either pump or motor.

Well No. 4 supplies the domestic service of Colton. It is of special interest owing to the grouping of the wells that are operated from one centrifugal pump. The pump is 16 feet below the surface of the ground, in a pit. The suction pipe from the pump is

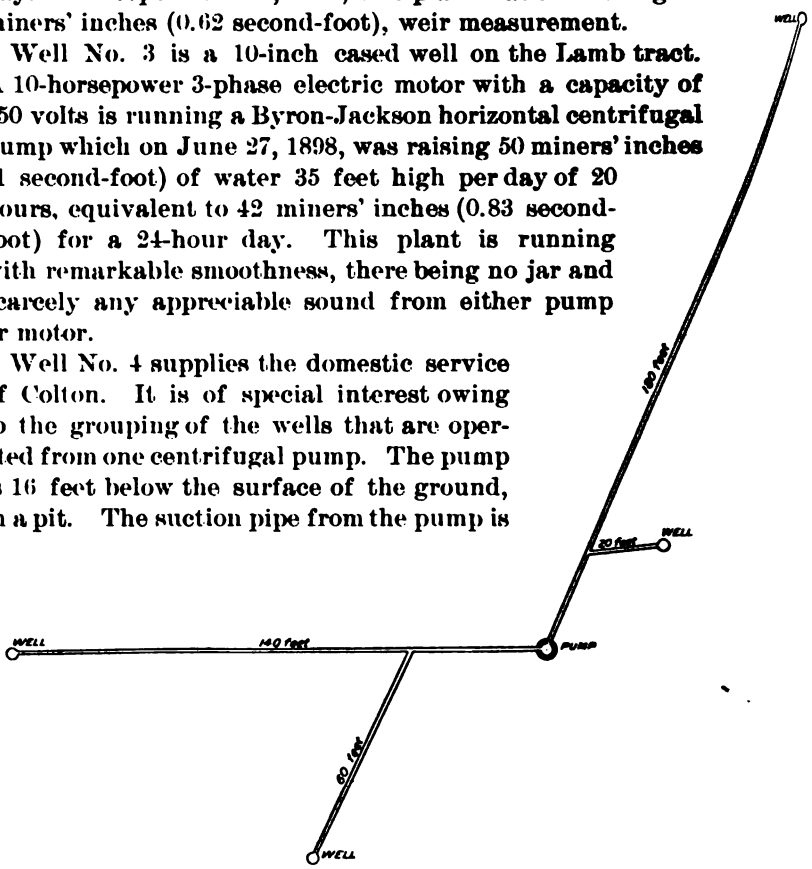


FIG. 1.—Plan of city of Colton pumping plant, showing group of wells operated by one centrifugal pump.

led to four cased wells. A deep trench was dug for these pipes. Fig. 1 shows the location of the wells and pump. This plant is located northwest of the Santa Fe Railroad, at the crossing of Lytle Creek. The pump was originally situated on the surface of the ground, but during the summer of 1898 it was lowered 16 feet, all of the connections of the wells being lowered also. The pump is a No. 8 Byron-Jackson vertical centrifugal, and is operated by a General Electric 20-horsepower 3-phase motor, which is developing 24 horsepower. On June 27, 1898,

A. PUMPING PLANT NEAR EL MONTE.

B. AIR-PUMPING PLANT NEAR COLTON.

110 miners' inches (2.2 second-feet) of water were being pumped, and on September 22, 1898, 150 miners' inches (3 second-feet), per day of 20 hours. The wells are all 10-inch cased wells. The pumps were lowered because of the falling of the water plane. The plant is entirely successful. A plant of similar design is located near Exeter, Cal., in the bottoms of Kaweah River.

Pomeroy & Marble wells.—The pumping plant of the Colton Terrace Citrus Land Company is at the corner of Mount Vernon avenue and Mill street, San Bernardino. A No. 4 Byron-Jackson horizontal centrifugal pump is run by an 8-horsepower gasoline engine. There is one well (cased) 100 feet deep, from which on June 18, 1898, 40 miners' inches (0.80 second-foot) were being lifted 32 feet. On that date there was also an artesian well furnishing water to this system from this locality. The latter well was flowing 40 miners' inches (0.8 second-foot).

Colton Terrace Orange Land and Water Company.—The wells of this company are four in number and are from 200 to 300 feet deep. They are 7-inch cased wells and are about 150 feet apart. This plant is of special interest, as the water is lifted by an air system. A 20-horsepower single-phase electric motor costing $700 was originally used to operate a Stillwell-Bierce air compressor. The electric motor was a failure and it was replaced by steam. From the air compressor the air is conveyed through a reservoir to a distributing pipe system. Thirteen horsepower is now being expended; but it is proposed to increase the number of wells, when more power will be required. The wells are bored and cased and a ¾-inch air pipe is run down to almost the bottom of each well. A stopcock is placed near each well to regulate the volume of air entering it. (See Pl. VIII, *B*.) The water is raised by the expansion of the air in the lower portion of the well pipe. The feature of special value in the system is that the lifting force can be indefinitely distributed to the numerous wells in the various localities. The illustration (Pl. VIII, *B*) shows a well into which an excessive amount of air has been admitted. Ordinarily just enough air is passed to produce a flow about 2 or 3 inches above the top of the well. The water stands naturally at a level of 20 feet below the surface. On June 30, 1898, the wells were producing 98.5 miners' inches (1.97 second-feet). This system of pumping does not as a rule give a working efficiency of more than 35 per cent and is proving a disappointment in several localities. In 1900 this method of pumping had been discontinued at this plant.

In Pl. VIII, *A*, is shown a pumping plant near El Monte. The water supply is from five cased wells in the gravel beds below the mouth of San Gabriel Canyon. The output is approximately 500 miners' inches.

Bloomington pumping plants.—The water flowing in the Bloomington flume is a combination of 100 miners' inches (2 second-feet) of

Lytle Creek water for the domestic supply of the city of San Bernardino and the output of three pumping plants in the Lytle Creek Basin. The irrigation water is being used near Bloomington, on the Citrus Belt irrigation district. The pumping plants are—

No. 1: A 20-horsepower gasoline engine expending three-fifths of its indicated power is pumping from a 10-inch cased well 400 feet deep. A No. 5 Byron-Jackson centrifugal pump is used, which on September 12, 1898, was lifting 56 miners' inches (1.12 second-feet).

No. 2: A 20-horsepower Daniel Best gasoline engine using 16 horsepower is running a Byron-Jackson centrifugal pump which lifts from a 10-inch cased well 469 feet deep 100 miners' inches (2 second-feet) of water. The water is raised 22 feet. On June 18, 1898, the plant was pumping 115 miners' inches (2.3 second-feet) and on September 12, 1898, it was pumping 100 miners' inches (2 second-feet).

A Pelton wheel is run from 100 miners' inches of water, which is dropped 80 feet from the Lytle Creek Improvement Company's canal, about 1½ miles north of the base line at the west bank of the Lytle Creek Wash, and develops 24 horsepower. On June 18, 1898, 110 miners' inches (2.2 second-feet) of water were being raised 46 feet from two wells and conveyed to the Citrus Belt irrigation district, near Bloomington.

Minor pumping plants.—Johnson & Hubbard have two 10-inch cased wells, one 190 and the other 260 feet deep. In June, 1898, a 3-phase electric motor developing 26 horsepower and a Byron-Jackson centrifugal pump were used to lift 120 miners' inches (2.4 second-feet) of water 40 feet high. The well furnishing the supply is located near the corner of Mill street and Mount Vernon avenue, San Bernardino. This water irrigates orange land north of Colton. The plant is used at intervals of a few days.

A well 2 miles northeast of San Bernardino is operated by an electric motor and a centrifugal pump. On September 9, 1898, it was discharging 25 miners' inches (0.50 second-foot). The water is being used on the Chinese gardens at the point of development. This well is pumped from only at intervals of about ten days. It is at the corner of the base line and Waterman avenue.

There are several other small pumping plants using water a few days each month which are not described here, because they are of relatively small importance.

STREAMS TRIBUTARY TO SAN BERNARDINO VALLEY ABOVE AND BELOW SLOVER MOUNTAIN.

For the purpose of making comparisons between the surface waters entering San Bernardino Valley above and below Slover Mountain, the following table of discharge measurements made in the summer of 1898 is introduced. It must be remembered that the summer of 1898 was preceded by a series of unusually dry years, and that the streams of the State were then at an extremely low stage. Mill Creek and Santa Ana River were visited by local storms during the latter part of August, and the flow from the Santa Ana had been specially reenforced by the water discharged from the Bear Valley reservoir, which regulates the flow from 54 out of 188 square miles of its drainage basin. The flow of Plunge Creek has been reenforced by development works in the bed of its canyon.

Discharge measurements of mountain streams in San Bernardino Valley above Slover Mountain, 1898.

Stream.	Point of measurement.	Date.	Discharge.	Date.	Discharge.
			Sec.-feet.		*Sec.-feet.*
San Timoteo Creek	Above Brookside[a]	June 12	1.00	September 8	0.50
Mill Creek	Crafton divide	do	18.10	do	13.07
Do	MacIntosh development.	do	.28	do	.28
Santa Ana River	At Warmsprings (including Bolen tunnel, 1.24).	do	40.30	do	37.91
Plunge Creek	At headworks	do	2.26	September 9	.20
City Creek	do	June 11	3.03	do	.07
East Twin Creek	Canal and development water.	do	2.05	do	.73
West Twin Creek	Headworks and Hot Springs.	do	2.13	do	.38
Lytle Creek	Anglo-American Canaigre Co.	June 10	10.73	August 27	10.01
Total		June	79.88	September	63.15
Missing or return water		June	71.25	September	78.31
Discharge from wells		do	66.86	do	66.38
Total		June	138.11	September	144.69
Deduct flow from surrounding mountain streams.		do	79.88	do	63.15
Excess of return water		June	58.23	September	81.54

[a] Estimated.

Discharge measurements of mountain streams in San Bernardino Valley below Slover Mountain, 1898.

Stream.	Point of measurement.	Date.	Discharge.	Date.	Discharge.
			Sec.-feet.		*Sec.-feet.*
San Antonio Creek	Division weir	June 2	6.43	August 26	5.18
Cucamonga Creek	In canyon	do	[a]2.08	do	1.04
Deer Creek	At headworks	do	[a]1.40	do	.70
Coldwater Creek	In canyon	July 1	.46	July 31	.16
Temescal artesian wells	do	do	7.00	August 30	7.00
Temescal Creek	Below lake	do	3.75	August —	3.00
Total			21.12		17.08

[a] Estimated.

Return waters in San Bernardino Valley below Slover Mountain and above Riverside Narrows, 1898.

Stream.	Point of measurement.	Date.	Discharge.	Date.	Discharge.
			Sec.-feet.		*Sec.-feet.*
Lower Riverside canal	Near headworks at E. Riverside.	June 17	10.27	August 27	8.50
Spring Brook	South of Rubidoux Mountain.	June 19	2.92	August 28	1.27
Evans ditch	Right bank, ¼ mile below bridge.	do	5.68	do	4.87
Rubidoux canal	Right bank, 1 mile south of county line.	do	8.94	August 27	8.50
Santa Ana River	4 miles below Riverside.	June 20	47.63	August 29	39.05
Total		June	75.44	August	62.19

Return waters in San Bernardino Valley between Riverside Narrows and the lower Santa Ana Narrows below Rincon, 1898.

Stream.	Point of measurement.	Date.	Discharge.	Date.	Discharge.
			Sec.-feet.		*Sec.-feet.*
Small ditch	Right bank, 2 miles below Riverside Narrows.	June 20	3.75	August	[a]3.75
Griffiths ditch	Right bank, sec. 28, T. 2 S., R. 6 W.	do	9.99	do	[a]9.99
Townsend ditch	Left bank, sec. 28, T. 3 S., R. 7 W.	do	4.80	do	[a]4.80
Small canal	Left bank, 2 miles below Rincon.	June 21	3.18	August 29	4.15
Cucamonga developments	At Red Hills	June	[a]6.80	September 9	[b]6.80
Santa Ana River	At lower narrows below Rincon.	June 21	79.81	August 29	62.67
	Total	June	108.33	August	92.16
Do	At Riverside Narrows.	do	47.63	do	39.05
Return water between Riverside and Rincon Narrows.		do	60.70	do	53.11
Total returning between Slover Mountain and Riverside Narrows.			75.44		62.19
Total returning between Slover Mountain and Rincon.			136.14		115.30
Surrounding mountain streams between Slover Mountain and Rincon.			21.12		17.08
Total excess of return water between Slover Mountain and Rincon.			115.02		98.22
Excess above Slover Mountain.			58.23		81.54
Grand total excess of return water in San Bernardino Valley above Rincon.			173.25		179.76

[a] Estimated. [b] Includes 1 second-foot developed at mouth of Cucamonga Canyon.

idering the volume of return water at Riverside Narrows in
er of 1898, as compared with the amount of irrigation water,
that is applied for irrigation below the Colton or Bunker Hill
ld be included. A divide occurs about 1 mile west of Arling-
west of which the drainage is into Temescal Creek and not
a Ana River above Riverside Narrows. A portion of the
the Riverside Water Company and the Gage canal—a vary-
tity, probably 1,000 miners' inches in average volume—is
alfalfa fields and orange lands south of this divide. It is
sible, however, that a portion of the water applied to the
ıds north of the divide and southwest of Riverside finds its
e north of the divide.

Discharge measurements of Santa Ana River.

	Point of measurement.	Discharge.	
		Miners' in.	*Sec.-feet.*
	Jurupa Narrows	505.0	10.10
	do	525.0	10.50
	Auburndale bridge	728.5	14.57
	Jurupa Narrows	425.5	8.51
	Auburndale bridge	664.5	13.29
	Jurupa Narrows	474.0	9.48
	Auburndale bridge	709.5	14.19
	Jurupa Narrows	550.0	11.00
	Auburndale bridge	777.5	15.55
	Jurupa Narrows	560.0	11.20
	Auburndale bridge	832.5	16.65
	Jurupa Narrows	937.9	18.76
	Auburndale bridge	1,112.5	22.25
	Jurupa Narrows	775.0	15.50
	Auburndale bridge	1,281.5	25.63
	Jurupa Narrows	1,469.1	29.38
	Auburndale bridge	2,171.4	43.43
	do	2,655.0	53.10
	do	2,902.0	59.83
	do	2,722.0	54.45
	do	3,487.0	69.74

foregoing measurements those for 1888 to 1892 were made
Finkle while he was chief engineer of the Jurupa Land and
ompany and the Stearns Ranchos Company. These meas-
show the gradual increase, despite the drought, in volume
the river at this point, due to the extension of irrigation on
ve.

Estimated monthly discharge of Santa Ana River and Santa Ana canal 2 miles above mouth of its canyon above Redlands, near Warmsprings.

[Drainage area, 188 square miles.]

Month.	Discharge in second-feet.			Run-off.		
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Depth in inches.	Second-feet per square mile.
1896.						
September	91	41	69	4,124	0.41	0.37
October	186	54	71	4,372	.44	.38
November	56	34	37	2,148	.21	.19
December	48	37	39	2,435	.24	.21
1897.						
January	104	35	68	4,179	.41	.36
February	585	77	185	10,282	1.02	.98
March	465	70	124	7,014	.75	.66
April	190	113	150	8,899	.88	.79
May	113	48	76	4,690	.46	.40
June	86	60	79	4,723	.47	.42
July	102	70	83	5,077	.50	.44
August	100	54	75	4,628	.46	.40
The year	585	35	88	62,571	6.25	.47
1897.						
September	81	58	67	3,968	.39	.35
October	270	45	54	3,347	.33	.29
November	59	40	45	2,678	.27	.24
December	38	29	33	2,040	.21	.18
1898.						
January	67	42	49	2,987	.30	.26
February	86	43	48	2,688	.27	.26
March	51	36	40	2,448	.24	.21
April	43	37	39	2,333	.23	.21
May	157	34	61	3,727	.37	.32
June	62	40	48	2,840	.28	.25
July	58	38	43	2,625	.26	.23
August	61	36	43	2,653	.26	.23
The year	270	29	48	34,334	3.41	.25
1898.						
September	River 45.0	28.0	38.0	2,223	0.22	0.20
	Canal	.....	2.0			
October	River 36.0	19.0	26.0	1,581	.16	.14
November	...do 34.0	18.0	22.0	1,295	.13	.12
December	...do 22.0	22.0	22.0	1,364	.14	.12
1899.						
January	River 34.0	21.5	25.9	1,593	.16	.14
	Canal	.....	2.0			
February	River 34.0	26.5	27.3	1,516	.15	.15
	Canal	.....	4.0			
March	River 48.0	24.0	31.6	1,943	.19	.17
	Canal	.....	7.0			
April	River 34.0	21.5	24.5	1,458	.14	.13
	Canal	.....	5.0			
May	River 26.8	19.0	22.2	1,365	.14	.12
	Canal	.....	3.0			
June	River 34.0	19.0	22.1	1,315	.13	.12
	Canal	.....	0.0			
July	River 28.5	19.0	22.3	1,371	.14	.12
	Canal	.....	0.0			
August	River 19.0	11.0	12.7	781	.08	.07
	Canal	.....	0.0			
The year	48.0	11.0	24.7	17,795	1.78	.17
1899.						
September	12	10	12	690	0.07	0.06
October	19	12	17	1,015	.10	.09
November	49	17	21	1,269	.13	.11
December	36	18	23	1,427	.14	.12
1900.						
January	36	19	23	1,414	.14	.12
February	23	20	22	1,222	.12	.12
March	28	20	23	1,414	.14	.12
April	43	19	25	1,488	.14	.13
May	350	20	57	3,505	.35	.30
June	25	19	22	1,309	.13	.12
July	25	11	19	1,168	.12	.10
August	12	9	11	676	.07	.06
The year	350	9	23	16,596	1.65	.12

Estimated monthly discharge of Santa Ana River and Santa Ana canal 2 miles above mouth of its canyon above Redlands, near Warmsprings—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean		Depth in inches.	Second-feet per square mile.
1900.						
ptember	16	11	12	714	.07	.06
ctober	16	12	14	861	.08	.07
ovember	1,564	14	107	6,367	.63	.57
ecember	31	25	28	1,722	.17	.15
1901.						
nuary	600	31	78	4,796	.47	.41
bruary	540	48	194	10,774	1.07	1.03
arch	114	45	68	4,181	.41	.36
pril	107	39	43	2,559	.26	.23
ay	68	35	42	2,582	.25	.22
ne	44	30	37	2,202	.22	.20
ly	42	34	38	2,337	.23	.20
ugust	200	31	50	3,074	.31	.27
The year	1,564	11	59	42,169	4.17	.31

Drainage areas of Santa Ana River above Rincon.

	Square miles.
outh of Mill Creek	10.0
ill Creek	46.2
anta Ana River	208.2
lunge Creek	17.1
eservoir between Plunge and City creeks	2.7
ity Creek	21.6
rainage between City and Sand creeks	1.9
and Creek	3.2
ittle Sand Creek	1.6
rainage between Little Sand Creek and East Twin Creek	2.5
ast Twin Creek	9.2
West Twin Creek	5.3
rainage between West Twin Creek and Devils Canyon	4.0
evils Canyon	7.1
ajon Pass Basin	88.0
ycamore Flat	2.8
ytle Creek	51.9
Total mountain drainage above Colton	483.3
rafton Hills and San Timoteo Basin	135.0
an Bernardino valley lands above Colton	132.0
Total drainage area above Colton	750.3

Mountain drainage above Rincon and below Colton.

	Square miles.
rainage north of Grapeland	2.7
an Savain Canyon	2.4
lorse Canyon	1.9
ast Etiwanda Canyon	3.2
ay Canyon	6.9
eer Canyon	4.2
rainage between Deer Canyon and Cucamonga Canyon	3.7
ucamonga Canyon	11.0

	Square miles.
Drainage between Cucamonga Canyon and San Antonio Canyon	1.2
San Antonio Canyon	26.7
Thompson Creek	5.5
Liveoak Creek	2.7
Total in mountains	72.1
Foothills around Riverside	62.0
Flat valley land between Rincon and Colton	393.0
Temescal Creek hills below Elsinore Lake	163.1
Chino Creek foothills	22.5

Summary of drainage areas.

	Square miles.	
Mountains above Colton	483.3	
Mountains above Rincon and below Colton	72.1	
Total in mountains above Rincon		555.4
Hills above Colton	135.0	
Hills around Riverside	62.0	
Hills of Temescal Creek below Lake Elsinore	163.1	
Hills of Chino Creek	22.5	
Total in hills above Rincon		382.6
Valley above Colton	132.0	
Valley below Colton and above Rincon	393.0	
Total in valley above Rincon		525.0
Total drainage area above Rincon		1,463.0

The precipitation for the seasons 1896–97 and 1900–1901 was about normal. Each year, however, was preceded by droughts. The discharge in second-feet per square mile of drainage basin of Santa Ana River proper, as given in preceding tables, was 0.45 second-foot per square mile in 1896–97, and 0.31 second-foot in 1900–1901. An estimated discharge for normal years of 0.40 second-foot per square mile from the mountainous portion of the basin above Colton is believed to be conservative. As the percentage of run-off increases with the depth of rainfall, the average annual discharge is greater than the run-off in years of average rainfall. The Bear Valley reservoir, which regulates the discharge from a portion of the basin of Santa Ana River, was completely emptied during both of the years mentioned, and consequently does not affect the totals. A portion of the larger floods are known to pass Colton, and are permanently lost so far as the gravel beds above Colton are concerned. Little surface run-off would occur from the flat and sandy valley lands and hills, but certainly an appreciable amount of the rainfall would sink into the ground and increase the underground supply. The latter supply is believed to be sufficient to offset the loss due to a portion of the larger floods passing the Colton dike unabsorbed. It is not claimed that these quantities are capable of exact determination. Many and expensive observations would be necessary to ascertain this, but it is thought that an estimate based upon existing data and experiences

gained elsewhere will be of interest on this important subject. While the run-off per square mile of the Cajon Pass Basin is known to be less than that of the Santa Ana proper, that of Mill Creek and Lytle Creek is greater, and the Santa Ana Basin is probably typical of the average. The estimated annual run-off, in second-feet per square mile, from the 483 square miles of mountain drainage basins tributary to San Bernardino Valley above Colton, assuming the run-off to be 0.40 second-foot per square mile, is 193.3 second-feet. During average years probably 50 per cent of this is diverted for irrigation at the mouths of the mountain canyons, and half of the water applied for irrigation may be assumed to be lost by evaporation, the remainder sinking into the ground. Thus one-fourth of the discharge from the mountains may be considered as permanently lost during average years, leaving a net remainder of 75 per cent, or 145 second-feet, as a reasonable estimated annual recharge of these gravels.

In June, 1898, the total seepage and return water entering San Bernardino Valley above Rincon was 274.25 second-feet, as shown in the foregoing tables, and at the same time the aggregate flow from the surrounding mountain drainage basins was 101 second-feet, making a total of 375.25 second-feet. The develcped water around Pomona (amount not known), however, is not included, and portions of the return water obtained near Colton and used around Riverside doubtiess return to the river above Rincon. It is difficult, however, to analyze the situation further than has been done. Despite the recent dry years the increased flow of the river at Auburndale bridge is in all probability due to increased irrigation in the valley, particularly near Riverside, and is especially significant.

The Cucamonga Water Company derives its water from the Red Hills. The company supplies Cucamonga proper, also North Ontario, and irrigates about 5,000 acres of citrus fruits. In August, 1898, there were in addition 52 miners' inches (1.04 second-feet) of water developed at the mouth of Cucamonga Canyon. The Red Hills are so named from the red clay occurring there, which forms a dike across the sand and gravel drainage lines of Cucamonga Creek. This forces the underground water to the surface, where it appears in springs and cienagas. There is an aggregate length of 8,000 feet of tunnels in this water-bearing land. There are 36 miles of 6-inch drain tiles in the distribution system.

The following is a compilation of all available measurements:

Discharge measurements, in miners' inches, of cienagas and water developments at Red Hills, near Cucamonga.

EAST SIDE.

Date.	Observer.	Creek div. box, 30-inch line.	Div. box No. 1, 16-inch line and Y tunnel (built 1886-87).	China cienaga.	Lone Star spring or tunnel.	Y tunnel (built prior to 1886).	Cienaga below tunnel No. 1.	Total without Lone Star.	Total.
Sept. 26, 1885	Wm. M. Fitzhugh	225.36	.....	51.73	[a]2.02	9.61 6.61 16.22	.....	293.31	295.33
Nov. 30, 1886	J. P. Culver	261.43	64.67	11.46	2.02	.....	.....	337.56	339.57
July 24, 1887	F. Eaton	147.50	169.50	[a]10.00	[a]2.00	163.00	.....	327.00	329.00
July 13, 1888	J. P. Culver	155.78	183.61	18.10	[b]13.59	138.62	46.43	357.49	371.08
July 13, 1889	E. T. Wright	184.58	163.57	13.27	9.78	136.23	48.35	361.42	371.20
July 14, 1890	....do	260.03	228.53	17.32	10.85	156.01	72.52	505.88	516.73
Do	J. P. Culver	266.82	238.04	18.50	11.25	165.55	72.49	525.36	534.61
July 14, 1893	E. T. Wright	.....	.....	.....	.....	152.42	.....	.....	.....
Sept. 15, 1894	....do	160.31	182.84	13.14	[a]8.00	141.10	41.74	356.29	361.29
June 12, 1895	....do	198.53	154.87	21.00	[a]7.00	[a]110.60	[a]44.27	374.40	381.40
Aug. 20, 1896	F. E. Trask	132.40	137.90	11.25	[a]7.00	.....	.....	281.55	288.55
Aug. 10, 1897	....do	104.90	120.10	10.50	[a][c]9.42	.....	.....	235.50	244.92
Aug. 5, 1897	N. W. Stowell	.....	.....	.....	9.42	.....	.....	.....	.....
Aug. 13, 1898	F. E. Trask	76.68	95.91	7.84	[d]47.00	.....	.....	180.43	227.43
Apr. 1, 1899	N. W. Stowell	107.25	98.20	.....	.....	.....	.....	205.45	.....
Do	Newman and Finkle	107.25	98.20	[a]5.00	[a]35.60	72.60	.....	210.45	246.05
Aug. 21, 1899	E. T. Wright	[f]91.58	80.95	.....	(g)	56.17	24.78	172.53	[h]199.53 247.53
Feb. 3 and 5, 1900.	Newman, Trask, and Finkle.	[f]97.06	77.22	.....	17.06	54.88	.....	174.28	191.34

[a] Estimated.
[b] Tunnel.
[c] Extent of tunnel begun August 11.
[d] Measurement by N. W. Stowell.
[e] March 15.
[f] Including China cienaga.
[g] Flow, 27.00; pumped, 75.00.
[h] Flow.

Discharge measurements, in miners' inches, of cienagas and water developments at Red Hills—Continued.

WEST SIDE.

Date.	Observer.	Spring northwest of tunnel No. 2, portal.	West of cienaga D.	Picnic spring, cienaga C.	Artesian wells Nos. 1 and 2.	Tiburcio spring.	Tunnel No. 2, on 90-acre tract.	China garden.	Stowell wells and tunnel above 90-acre tract.	Rain previous season.	Total on 90-acre tract.	Grand total for Red Hills.
Sept. 26, 1885	Wm. M. Fitzhugh.	56.47	45.27	[a]9.00	.....	[a]1.00	.....	.....	.....	10.81	111.74	406.07
Nov. 30, 1886	J. P. Culver	9.50	5.70 97.80 .90 104.40	18.40	.....	2.16	.....	(b)	.....	21.83	134.46	474.03
July 24, 1887	P. Eaton	13.67	31.90	10.00	Fall '97	[a]1.00	.....	[a]16.76	.....	14.50	73.33	402.33
July 13, 1888	J. P. Culver	3.14	38.89	5.38	15.14	1.59	[c]17.70	16.76	.....	17.76	98.00	469.68
July 13, 1889	E. T. Wright ...	3.94	40.53	17.33	15.14	1.81	54.02	[a]16.76	.....	20.97	149.53	520.73
July 14, 1890	.....do	3.08	71.98	30.53	13.98	.92	[d]73.82	[a]16.76	.....	25.45	211.07	727.80
Do	J. P. Culver	3.14	81.78	31.47	14.29	2.38	75.42	[a]16.76	.....	.....	225.24	759.85
June 29, 1893	E. T. Wright ...	.....	.....	13.29	.....	.....	.....	.....	.....	19.82	.....	.....
July 14, 1894	.....do	.....	.....	.....	.....	.....	36.45	.....	.....	.....	.....	.....
Sept. 15, 1894	.....do	.....	.....	.....	.....	.....	.....	.....	.....	8.13	.....	.....
June 12, 1895	.....do	.....	.....	.....	.....	.....	.....	.....	.....	20.98	.....	.....
June 14, 1896	N. W. Stowell ..	.00	22.00	1.00	23.00	.....	[a]18.00	.....	.00	.....	64.00	352.55
Aug. 20, 1896	F. E. Trask	.....	.....	.....	.....	.....	.....	.....	.....	8.11	.....	
Mar. 2, 1897	N. W. Stowell ..	.....	.....	.....	.....	.....	.....	.....	46.00	.....	.....	.....
Aug. 10, 1897	F. E. Trask	.00	.....	.....	.....	.....	.....	.....	.....	16.74	.....	
Aug. 5, 1897	N. W. Stowell ..	.00	20.00 7.00 27.00	[a].50	[f]20.25	.00	41.40	.00	.....	.....	89.15	334.07
Aug. 13, 1898	F. E. Trask	.00	.....	.....	.....	.....	.....	.....	.....	8.24	.....	
Aug. 14, 1898	N. W. Stowell ..	.00	[a]24.00	[a].50	[b]13.00	.00	22.00	.00	.....	.....	63.50	290.93
Apr. 1, 1899	.....do	.....	.....	.....	.....	.....	.....	.....	.....	7.49	.....	.....
Do	Newman and Finkle.	.00	[i]15.49	.....	7.90	.....	.....	.....	.....	.....	.....	.....
Aug. 21, 1899	E. T. Wright ...	.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Aug. 25, 1899	E. T. Wright and F. C. Finkle.	.....	3.13	.....	2.68	.....	61.80	.....	92.40	.....	67.61	267.14
Feb. 3 and 5, 1900.	Newman, Trask and Finkle.	.00	3.91	.....	1.45	.....	.....	.....	.....	.....	.....	
Feb. 11, 1900	Trask and Finkle.	.....	3.81	.56	1.20	.....	55.90	.....	76.25	.....	61.47	252.81

[a] Estimated.
[b] China garden included in cienaga D.
[c] Construction begun in January, 1888.
[d] Length, 2,600 feet.
[e] Caved in.
[f] August 4, well No. 2 cut.
[g] June 12, not pumped.
[h] July 24, not pumped.
[i] March 15.

The following diagram, fig. 2, shows the relation that exists between the rainfall and developed water at Red Hills:

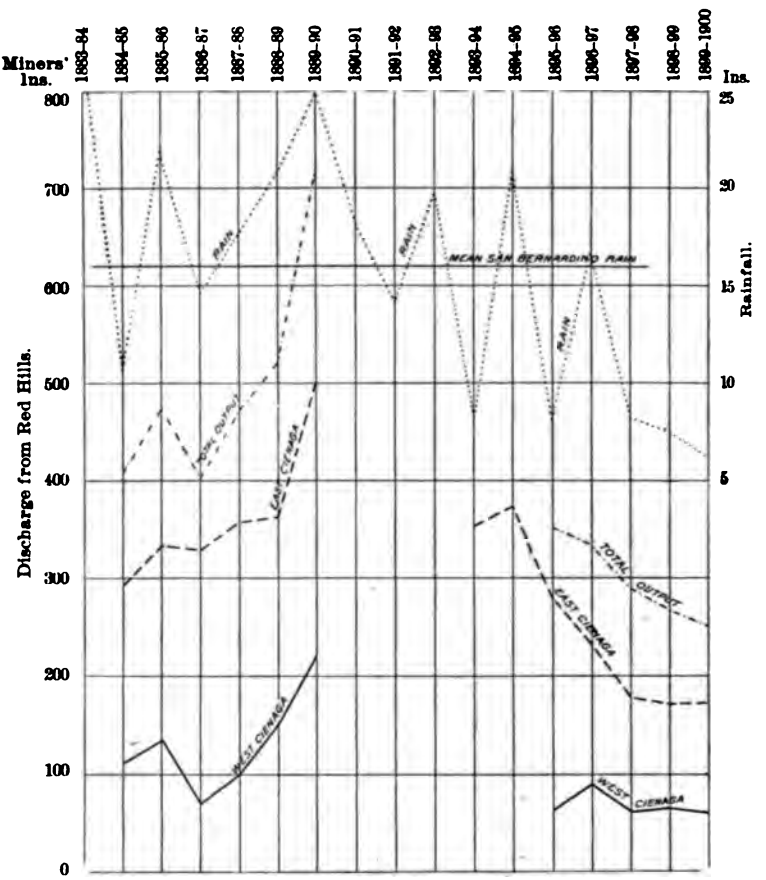


FIG. 2.—Diagram showing relation of rainfall to developed water at Red Hills. Dotted line shows rainfall, in inches, as measured at San Bernardino; dot-and-dash line shows discharge, in miners' inches, from all of the developments at Red Hills, exclusive of the Stowell wells; dash line shows discharge, in miners inches, of east cienagas and Y tunnel, exclusive of Lone Star; heavy solid line at bottom shows discharge, in miners' inches, from 90-acre tract at west end of hill, exclusive of the Stowell wells.

From 1888 to 1900 many lineal feet of tunnels were run and numerous wells were sunk at the Red Hills for new water supplies, but in spite of this development the amount of water available materially diminished—from 406 miners' inches to 253 miners' inches. Although this decrease is influenced by the diminished rainfall during the period, it is improbable that all of the work performed resulted in much if any permanent benefit to the irrigators. The gravel beds above the Red Hills are much smaller than those above Colton, and consequently are more quickly drawn down. The chief question in situations of this kind is how large a water supply can be counted upon to recharge the underground reservoir. This can be determined by measuring the area of the tributary drainage basin from the topo-

atlas sheets of the United States Geological Survey. To this uld be applied the mean annual run-off. In this case the nual run-off, in second-feet per square mile, can be obtained tudy of records of discharge of San Gabriel and Santa Ana The Red Hills are shown on the Cucamonga atlas sheet of ogical Survey, and are 2 miles northeast of North Ontario.

ited monthly discharge of San Gabriel River and canals near Azusa.

[Drainage area, 222 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1895.						
	39	29	32.0	1,928	0.16	0.14
	32	27	29.0	1,811	.16	.13
	50	29	40.0	2,392	.20	.18
	57	37	42.0	2,561	.22	.19
1896.						
	51	26	37.0	2,275	.20	.17
	54	36	41.0	2,358	.19	.18
	169	38	111.0	6,825	.58	.50
	91	40	54.0	3,213	.28	.25
	42	29	36.0	2,214	.18	.16
	26	13	19.0	1,131	.09	.08
	15	9	12.0	738	.06	.05
	36	9	14.0	861	.07	.06
ar	169	9	39.0	28,307	2.39	.17
1896.						
	18	11	13.0	774	0.07	0.06
	188	10	24.0	1,476	.13	.11
	40	15	19.0	1,131	.09	.08
	37	17	22.0	1,353	.12	.10
1897.						
	147	25	58.0	3,617	.29	.26
	1,713	64	345.0	19,146	1.58	1.55
	1,765	294	406.0	28,623	2.42	2.10
	370	201	294.0	17,519	1.48	1.32
	196	94	145.0	8,851	.75	.65
	91	54	68.0	4,033	.34	.31
	52	27	38.0	2,343	.20	.17
	34	22	26.0	1,613	.14	.12
ar	1,765	10	126.5	90,479	7.61	.57
1897.						
	23	18	21.0	1,228	0.10	0.09
	1,640	22	91.0	5,595	.47	.41
	34	31	33.0	1,860	.15	.14
	34	28	31.0	1,875	.16	.14
1898.						
	63	27	40.0	2,453	.20	.18
	70	32	40.0	2,241	.19	.18
	83	28	35.0	2,131	.18	.16
	37	25	33.0	1,960	.17	.15
	83	25	36.0	2,223	.19	.16
	30	14	19.0	1,159	.10	.09
	15	9	11.0	672	.06	.05
	9	5	7.0	456	.04	.03
ar	1,640	5	33.0	23,841	2.01	.15
1898.						
	10	6	8	467	0.04	0.04
	10	8	9	533	.05	.04
	11	8	10	580	.05	.04
	18	12	14	832	.07	.06
1899.						
	33	15	23	1,414	.12	.10
	28	20	22	1,244	.11	.10
	40	18	26	1,623	.14	.12
	28	16	21	1,262	.11	.10

Estimated monthly discharge of San Gabriel River and canals near Azusa—Co

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile
1899.						
May	17	12	14	842	0.07	
June	22	5	10	595	.05	
July	4	3	4	221	.02	
August	6	4	5	295	.03	
The year	40	3	14	9,878	.86	
1899.						
September	6	3	37	2,202	0.19	
October	35	4	12	738	.06	
November	24	10	14	833	.07	
December	39	16	20	1,230	.10	
1900.						
January	89	22	32	1,968	.16	
February	33	18	20	1,150	.09	
March	30	16	20	1,230	.10	
April	26	13	17	1,012	.09	
May	86	16	37	2,275	.20	
June	22	8	15	893	.08	
July	10	4	6	369	.03	
August	5	4	4	246	.02	
The year	89	3	20	14,146	1.19	
1900.						
September	6	3	4	238	0.02	
October	6	4	5	307	.02	
November	5,200	5	186	11,068	.93	
December	53	31	40	2,460	.21	
1901.						
January	1,450	28	169	10,391	.87	
February	2,605	137	696	38,654	3.27	
March	440	135	221	13,589	1.15	
April	130	95	110	6,545	.56	
May	272	83	121	7,440	.63	
June	93	41	63	3,749	.31	
July	41	24	30	1,845	.16	
August	27	15	20	1,240	.10	
The year	5,200	3	139	97,526	8.23	

Discharge measurements of mountain streams of San Gabriel Basin, 1898.

Stream.	Point of measurement.	Date.	Discharge.	Date.	Discharge.
			Sec.-feet.		*Sec.*
San Gabriel River	Power company headworks (includes developed water).	July 1	15.37	August 23	
Dalton Canyon	In canyon			August 25	
San Dimas Canyon	do			August 26	
Sawpit Canyon	do	July 1	.34	August 23	
Total		July	15.71	August	

Return waters of San Gabriel Basin near El Monte Narrows, 1898.

Stream.	Point of measurement.	Date.	Discharge.	Date.	Discharge.
			Sec.-feet.		*Sec.-feet.*
er ditch	El Monte road crossing	July 3	1.63	August 31	1.80
	Pumping plant	do	1.40	do	1.40
s ditch	In narrows	do	9.06	do	6.88
briel River	First channel—Baldwin's road.	do	8.79	do	7.81
	Old channel—Baldwin's road	do	6.18	do	6.17
	Camper's station	do	3.36	do	.63
ditch	San Gabriel Narrows	do	2.44	do	.00
briel River	Old Mission bridge	do	29.79	do	27.91
otal flow in narrows.		do	62.85	do	52.60
ain streams		do	15.71	do	7.49
xcess of return water.		do	47.14	do	45.11

r a description of the settlement of the San Bernardino and Red- districts, see the Nineteenth Annual Report of the United States ogical Survey, Part IV.

RIVERSIDE DISTRICT.

HISTORY.

e first irrigation movement in the Riverside district was made e Silk Center Association in November, 1869. This was a coloniz- nterprise for the production of raw silk. Arrangements were for the purchase of 5,000 acres of land from the Jurupa and doux ranchos, and 1,400 acres of Government land were occupied r the United States land laws. The town of Jurupa was started ese lands, the name being changed in 1870 to Riverside. This iation filed the first water notices for the settlement and began onstruction of a canal in 1870. Silk culture was abandoned the that the movement was initiated. New parties allied themselves the colonizing movement, and the Southern California Colony ciation was founded, with Judge J. W. North, president; Dr. Greves, secretary; Dr. K. D. Shugart, treasurer; and Mr. T. W. r, superintendent. Construction of the canals was begun in ber, 1870. The first canal was built during the winter of 1870–71, grade of 1 inch to 100 feet, from a point on the south or left bank nta Ana River about 2 miles below Colton. The total length 13.5 miles. It was 8 feet wide on the bottom, 12 feet wide on top, 3 feet deep; the alignment and grade were very irregular. It a capacity of a little more than 700 miners' inches (14 second-feet) to the Spanishtown flume, and 500 to 600 miners' inches (10 to cond-feet) below that point. The conduit to the Pachappa Arroyo from $50,000 to $60,000. During the fall of 1871 this ditch was ded to Terquisquite Arroyo. By 1875 the ditch had been im- ed so that it carried 1,000 miners' inches (20 second-feet), but at time not more than 500 acres were irrigated. This is now known

as the old upper canal of the Riverside Water Company. The diversion is by means of a brush dam, and the conduit is wholly in earth. There are no engineering features of interest.

In 1874 S. C. Evans, of Fort Wayne, Ind., and W. F. Sayward, of San Francisco, purchased 8,000 acres of land adjoining Riverside and united with the owners of the San Jacinto Sobrante Rancho, which is situated still farther to the south, to construct another canal from Santa Ana River for the irrigation of their lands. The former of the proposed settlements was called the New England Colony and the latter the Santa Ana Colony. The Southern California Colony Association began suit to prevent the construction, which had been already started, of the new canal across their lands. The dispute was ended by the New England and Santa Ana colonies purchasing, in May, 1885, a four-sevenths interest in the original association for the sum of $50,000. In April, 1875, the Riverside Land and Irrigation Company was organized by the members of the three original colonies or companies, and by March, 1877, this new company had absorbed all of the land and water holdings of its predecessors. In 1876 the new or lower canal of the New England and Santa Ana colonies was completed, at a cost of $120,000, and during the season about 2,000 acres were irrigated by the two canals. In July, 1879, the Riverside Canal Company, which was organized for the purpose, purchased all of the water rights and conduits of the Riverside Land and Irrigation Company, the latter receiving as compensation all of the capital stock of the new company. The value of each share was placed at $20, and 20,000 shares were issued. It was further agreed that the stock should be adjusted so as to correspond with the number of acres for which water was obtained. The avowed original intention of the company was to have each share of stock cover a particular acre irrigated; but the sale of stock in some instances was made to persons who had not bought land from the company but had obtained it from the Government. By this method of disposing of the stock of the canal company those originally in power found that they would soon lose control, and therefore they passed new resolutions, assigning two shares of stock to each remaining acre, the canal company holding the shares at a par value of $10 each, one share to be issued with each acre of land and the other share to remain in the hands of the company until it had sold the majority of its lands, when the landowner could at his option purchase it at the original price.

The purpose of the Riverside Land and Irrigation Company was primarily to promote the sale of its irrigated lands. As their affairs progressed and the lands were sold the company naturally desired to continue its benefits by handling the waterworks of the irrigators and by expanding its water rights over more lands. Water rates were advanced from $1.92 an acre, in 1878, to $2.23 an acre, in 1881. These movements on the part of the company were naturally opposed by the

gators, and a protracted struggle ensued. The irrigators organ- l the Citizens' Water Company with which to battle for their claims. out this time a State law was passed giving the county boards of ervisors the right to regulate water rates and compelling the con- ued delivery of water at uniform rates to irrigators to whom water l previously been sold. The Riverside Canal Company claimed t it had the right to charge such rates as would insure the main- ance of its plant and interest on the investment and to charge a nus of $20 to landowners holding no stock. To this the irrigators lied that the original investment had been more than returned to e Riverside Canal Company from the sales of its irrigated lands. e courts, as is usual in cases of this nature, were slow and indecisive their judgments. This dispute, which we see repeated in every igation locality, lasted from 1882 to 1885 and ended in the Holt mpromise. By this agreement the Riverside Water Company was ganized by the irrigators to deal in all classes of water property. ey issued 24,000 shares of stock covering certain specified lands, be an appurtenance thereof, two shares to apply to each acre, d afterwards to be transferable only with the land. Shares were ued for 6,000 acres of land then irrigated, and another 6,000 res were specified for which water could be sold as a surplus was veloped. This unirrigated land belonged to the old Riverside Land d Irrigation Company. It was transferred to the new company, called e Riverside Land Company, and one-half of the stock was issued to the verside Water Company and one-half to Evans and Felton, the lat- the controllers of the old Riverside Land and Irrigation Company d the Riverside Canal Company. The Riverside Water Company id to the Riverside Canal Company $70,120 in bonds and exchanged ock of the old company for stock in the new at the rate of two shares the old stock for one share of the new. The cost of the purchase the new company was about $120,000. Residents within the pre- ribed limits who did not own canal company stock were permitted purchase it at the rate of $10 a share, two shares to the acre. The igators thus control the Riverside Water Company, elect their offi- rs, and determine their own water rates. This method of manage- ent has proved successful, while both corporate and irrigation dis- icts have been continuously unsatisfactory. It is an interesting fact at no definite decisions were reached through the courts, but that ttlements were the result of compromise. The Riverside Water ompany now successfully operates the plant. It delivers water to e stockholders at cost, and has improved and extended its works y the sale of bonds secured by the property of the corporation and its ockholders.[a]

[a] The foregoing historical statement is largely obtained from Irrigation in Southern Cali- rnia, by William Ham. Hall, State engineer, 1888.

The general development of the Riverside district is shown in the following table:

Table showing commercial growth of Riverside.

Year.	Population.	Orange shipments.	Assessed valuation.	Post-office receipts.
		Carloads.		
1887		375	$3,586,933	$4,044
1888		725	3,978,699	10,288
1889		982	4,418,035	10,198
1890	4,682	1,500	4,588,890	11,591
1891		1,446	4,830,575	14,302
1892	7,395	2,100	5,834,000	15,458
1893		2,526	5,392,251	16,764
1894		1,928	4,958,247	16,243
1895		2,800	4,437,004	14,085
1896		2,018	4,588,181	14,147
1897	8,000	2,508	3,875,236	15,143
1898		4,000	[a] 4,984,566 [b] 3,038,603	16,513
1899		2,048	[a] 5,123,645 [b] 3,012,753	16,555
1900		[c] 3,700 [d] 4,300	5,490,895	19,336

[a] City valuation. [b] County valuation. [c] To date. [d] Estimated.

The city has two banks of deposit, one savings bank, thirteen churches, and eight schoolhouses. It has a debt of $120,000, and the tax rate is 65 cents on the hundred dollars. The ratio of its bank deposits and assessed valuation to its population makes it probably the first city in per capita wealth in the United States. The city covers 56 square miles, the corporate limits being extended to the outlying lands, largely for the purpose of local water and horticultural control. In June, 1893, it became the county seat of the newly formed county of Riverside.

The canals of the Riverside Water Company cover 12,000 acres of land, of which 8,500 acres are now being irrigated. The remaining 3,500 acres are to be sold and improved. The main canals aggregate 36 miles in length, while the lateral pipes, the flumes, the cemented and open ditches for distribution exceed 150 miles in length. Water is conveyed direct to every subdivision of the 8,500 acres under the irrigating system.

RIVERSIDE WATER COMPANY.[a]

WATER SUPPLY.

The Riverside Water Company obtains its supply from Warm Creek, from Santa Ana River, and from artesian wells.

Warm Creek has its source in San Bernardino Valley, 3½ miles east of the town of San Bernardino, and is fed entirely by springs and return water along its course. The flow is uniform, being about 80 second-feet during the irrigating season. It has no defined surface connection

[a] The writer is indebted to Mr. Kingsbury Sanborn for most of the information contained *herein regarding this* company.

A. HEADWORKS OF RIVERSIDE CANAL IN WARMSPRINGS CREEK.

B. HEADWORKS WEIR OF RIVERSIDE WATER COMPANY.

ith the mountain drainage line. Its source is largely near Harlem rings, about 4 miles east of the city of San Bernardino.

The surface water of Santa Ana River is all diverted near the outh of its canyon above Redlands, and for miles the bed of the eam below that point is totally dry during the irrigating season, t gradually the underflow comes to the surface at points south of e town of San Bernardino, and uniting with the return waters from igation on the mesas on the north side of the river amounts to 8 cond-feet and becomes a valuable adjunct to the Riverside Water mpany's supply.

The artesian wells of the Riverside Water Company are located on veral tracts of land, all situated in San Bernardino Valley east of lton, San Bernardino, and the dike previously referred to. They ry in depth from 68 feet to 590 feet, and in diameter of the casings om 6 inches to 11 inches. The largest is a 9-inch well near Harlem rings, 594 feet deep and flowing, on August 26, 1898, 3 second-feet water.

The distinctive feature of the water supply of the Riverside Water ompany is its constancy. Warm Creek is the principal source of pply. The volume that is available at the headworks of the canal ee Pl. IX) remains practically constant, winter and summer, dry ears and wet years, except when the unusual floods from the moun- in basins are projected far out into the valley, flowing continuously rough to the narrows. As has previously been explained, the sup- ly is largely regulated in the underground reservoirs of the valley. he point of diversion being at the lower level of the reservoir insures continuous flow, even during dry years. The driest cycle of seasons f which there are records of stream flow is the five last past, and it is laimed by the water company that its supply was equal to the nor- al during the summer of 1898. On June 30, 1898, there were flow- g in the canal at the old Colton mill, above all diversions, 3,473 iners' inches (69.46 second-feet) of water. This is considered a ormal summer flow from the various sources of supply.

Construction of the Davis well, which was leased by the owner, apt. Louis S. Davis, to the Riverside Water Company for the season f 1899, was started April 27, 1899. The well was completed May 12 f the same year. It is 510 feet in depth, has a 10-inch pipe, a No. 12 on casing, and the same size all the way down. The cost was $804. he water all comes from the bottom of the well. When first finished rose 34 inches above the top of the casing, and by weir measure- ent amounted to 350 miners' inches. The well is located in the ortheast corner of lot 17, block 44, of the 12-acre survey of the San ernardino Rancho. On October 2, 1899, it was flowing, by weir easurement, 233.7 miners' inches.

On April 3, 1900, the Riverside Water Company was successful in btaining another large flowing well in San Bernardino County, the

water in which rises 12 inches above the casing. The well yields more than 150 miners' inches, making it the second largest well in San Bernardino County. It is located near the Davis well. The strike came at a particularly opportune time, as Captain Davis refused to lease the Davis well to the water company this year (1900), and the water was shut off from the Riverside ditches about April 1, 1900. The strike was made at a depth of 540 feet. This well is the fourth in the district that is now flowing more than 100 miners' inches. The Riverside Water Company has a large tract of land in line with these wells.

MAIN CANAL.

The main canal of the Riverside Water Company has a capacity of 100 second-feet. It diverts water from Warm Creek, a half mile east of the town of Colton and just above the junction of Warm Creek with Santa Ana River, by means of a well-constructed brush dam. The canal follows along the west or right bank of Santa Ana River for a quarter of a mile. At that point a 6-foot drop is made through a turbine wheel which develops about 25 horsepower during the dry summer months. This power is used to pump 104 miners' inches (2.08 second-feet) of developed water from a pit and trench extending into and across the sandy bed of Santa Ana River. From this drop the water enters a cement-lined canal. Thence it crosses the Santa Ana in a substantial redwood box flume about 1½ miles long, supported the entire distance upon piling. (See Pl. LXIII, *B*, of the Twentieth Annual Report, Part IV, p. 554.) The flume box is 8 feet wide, 4 feet deep, and on a grade of 26 feet above the bed of Santa Ana River in the highest place. After crossing the river the water enters a 60-foot tunnel, then a short stone ditch, and finally the long tunnel, which is 3,250 feet in length, 7 feet and 8 inches wide at bottom, 8 feet and 4 inches wide at the 4-foot mark, and 6 feet high. The top of this tunnel is roofed with heavy timbers covered with redwood lagging and resting on brick piers laid in pure cement. The bottom and the walls between the piers are made of well-rammed concrete, the whole being covered with a coating of pure cement. After the water leaves the tunnel in its course toward Riverside it makes a drop of 40 feet at Highgrove and furnishes, from a Stillwell & Bierce turbine, 250 guaranteed theoretical horsepower, which is now used by the San Bernardino Electric Light and Power Company to develop electricity, which is supplied to Colton and San Bernardino for illumination and power purposes. At Riverside the upper canal is connected with the lower canal by a 32-foot fall, which furnishes power to the National Ice Company for the manufacture of ice. The canal runs through the city of Riverside, making four more drops before it reaches its destination in the Temescal Wash.

A. LINING RIVERSIDE WATER COMPANY'S CANAL WITH CEMENT PLASTER.

B. CEMENTED CANAL OF RIVERSIDE WATER COMPANY.

Owing to the loss of water by seepage and evaporation during the t summer months of the irrigating season, and to save the expense cleaning vegetation from the canals, it has been found economical plaster the banks (see Pl. X). The usual method followed is to first roughly wet the canal, when dry, by building earth dams at inter- ls which will bring the water as near the top of the canal as possible. e water is allowed to soak into the ground and the remainder is ained off. After the canal has again become dry enough to work is excavated to a subgrade three-fourths of an inch outside of the tion of the bank and below the true grade. The lining is extended each side of the top of the bank for a distance of 5 inches and a pth of three-fourths of an inch. Just before plastering, the banks the canal are thoroughly wet, by spraying or sprinkling. The ment mortar, which is applied to a depth of three-fourths of an ch, is composed of one barrel of pure Portland cement to four bar- ls of clean, sharp sand thoroughly mixed dry on a floor, after which fficient water is added to moisten to the proper consistency and the ole is again thoroughly mixed. The canal is first plastered on the les and a selvage of 5 inches is built on each side of the top; the ttom lining is put in last. It is finally completed by washing with o coats of liquid cement. After the cement mortar is in place the nal is kept moist for six days, so that it will harden with uniform lor.

MEASUREMENT OF WATER.

An important detail in connection with this canal system is the asurement and division of the water. Near the head of the main al, where it crosses the Southern Pacific Railway's main line to ma, is a weir which measures the greater portion of the water erted by the company. A device of local origin has been con- ucted for permanently recording the discharge over the weir. It nade in Riverside, by Mr. C. H. Watson, and costs, set up, about , or $40 in the shop.

AUTOMATIC WATER REGISTER.

This is a register for recording accurately the elevation of the sur- e of water in either a reservoir or a flowing stream. It consists of upright revolving cylinder the motion of which is regulated by ckwork, covered by the record sheet of paper, which is ruled in tical lines, each space representing one hour of time, and in hori- tal lines measuring the elevation, which is marked upon the record et by a pencil fixed upon an upright rod terminating at its lower remity in a float resting in the water. The register is inclosed in a stantial wooden box or case 45 inches in height, 17 inches in width, l 12 inches in depth, which is provided with a secure lock. The rod ending from the recording pencil to the float passes through the

Stationery	$59.72	
Breaks in canals	107.95	
Repairs	4,938.25	
Salaries	5,757.00	
Cleaning canals and laterals	4,062.10	
Expense (office rent, etc.)	654.94	
Night watch	90.20	
Zanjero wages	5,097.15	
Domestic water salary	1,200 00	
Feed	462.15	
Postage	186.50	
Pipe repairs	274.64	
Temporary water leased	3,459.14	
		$70,142.88
Total		1,252,439.84

Liabilities.

Capital stock	236,380.00
Bonds payable in 1912	812,500.00
Dividends (from land company)	20,000.00
Loss and gain	86,058.77
Accounts payable	62.50

Operating income.

Ranch	$1,897.32	
Water sales by the inch	59,454.10	
Water sales by the acre	5,673.60	
Water power	4,891.65	
Domestic water	24,662.65	
Rent	859.25	
		97,438.57
Total		1,252,439.84

The receipts of the company for water service are shown in the following table:

Receipts of Riverside Water Company for water service.

Year.	Irrigating system.	Domestic system.	Year.	Irrigating system.	Domestic system.
1886	$21,418.81	$120.10	1893	33,884.91	23,151.10
1887	24,919.47	1,658.95	1894	40,738.80	22,284.60
1888	23,830.44	3,672.30	1895	33,594.43	22,382.43
1889	26,394.16	9,525.00	1896	35,277.05	22,463.76
1890	33,516.00	13,058.45	1897	49,725.88	21,719.60
1891	37,421.45	19,209.83	1898	52,282.93	23,972.01
1892	39,557.10	22,349.30	1899	65,127.70	24,662.65

The capital stock of the Riverside Water Company is $240,000, divided into 24,000 shares of $10 each, intended to cover 12,000 acres, two shares of stock being issued for each acre of land. Of this entire capital stock, to December 31, 1899, there had been paid in and stock issued for $236,380, or 11,819 acres. The amount of cash expended by

the company to that date was $1,252,439; the value of the plant is estimated at $2,500,000. The amount expended annually since its organization, in purchase and construction, is shown by the following table:

Annual expenditures of Riverside Water Company in purchase and construction.

1885	$120,000.00	1893	$84,583.91
1886	27.00	1894	73,267.72
1887	598.56	1895	16,049.32
1888	64,657.28	1896	11,404.47
1889	311,962.02	1897	9,681.32
1890	41,362.22	1898	18,255.85
1891	178,666.59	1899	16,324.65
1892	59,118.72		

Water rates fixed by the board of city trustees of Riverside.

1885 to 1888, inclusive, 7½ cents for 1 miners' inch, 24 hours' run.
1889 to 1897, inclusive, 10 cents for 1 miners' inch, 24 hours' run, or $7 per acre per annum, unlimited service from pressure pipes.
1898 to 1900, inclusive, 15 cents for 1 miners' inch, 24 hours' run, or $10 per acre per annum, unlimited service from pressure pipes.

DOMESTIC SYSTEM.

Water for municipal and domestic purposes was at first obtained from the irrigating canals; but in 1886 the Riverside Water Company began the construction of its domestic system, by which artesian water for municipal and domestic uses is delivered through a well-conceived and comprehensive pipe system, under a pressure of not less than 70 pounds to the square inch. The capacity of the system is 3,000,000 gallons daily. The water supply is from eighteen artesian wells located in lot 4, block 65, San Bernardino Rancho, about 2½ miles east of the town of Colton. The wells vary in depth from 111 feet to 344 feet, and cost, on an average, $500 each.

In the fall of 1887 the first group, consisting of six 11-inch wells, were sunk to an average depth of 115 feet, and flowed, when finished, about 5 second-feet. These wells were sufficient to supply the domestic consumption of Riverside for several years; but as the demands for water increased the company found it expedient to construct more wells, which they did, using casings of smaller diameter and sinking the wells deeper in order to tap lower subterranean strata. The water from all of these wells is conducted through a gravity vitrified pipe line to a circular cement-lined reservoir, where it is aerified over a partition. (See Pl. VI, *B*.)

From the reservoir the water passes through three screens, of different size mesh, to a 17-inch steel pipe. Pipe of this size extends for a distance of 3.8 miles, when it is reduced to 16-inch steel pipe for the remainder of the distance (4.3 miles) to Riverside. The pipe line has a total fall of 172 feet to the center of the city of Riverside, and a capacity of 3,900,000 gallons daily. In the city the larger mains—6-inch, 8-inch, and 9-inch—run east and west and are connected

...streets with smaller pipes. The fire hydrants are ... large mains and afford excellent fire service.

GAGE CANAL SYSTEM.[a]

...anal is in Riverside and San Bernardino counties. It ... in the bed of Santa Ana River, in lot 4, block 69, Sa... Rancho; or a more specific description would be SW. ¼ ... R. 4 W., S. B. M. The initial point has an absolut... ...sea level of 1,035 feet. The terminal point of the cana... ...boundary of SE. ¼ sec. 19, T. 3 S., R. 5 W., S. B. M.... ...stance between the two points, following the line of th... ...miles. The construction of the canal proper was begu... ...55 and was finished as far as flume No. 9, over Terquis-... in the year 1886. The actual work of construction of ...ng portion was begun in the spring of 1888 and was practi-... ...leted during that year. The whole of the canal was exca-... ...enerally in the clay formation, on a grade of 2 and 3 feet to ... and to a uniform depth of 4 feet, with varying width of ...

...ccompanying map (Pl. I) shows the location of the canal in ... to all of the intermediate points and the adjacent territory. ...I, II, A, and XI, and figs. 3 to 14, inclusive, show features of ...

HISTORY.

...construction of the Gage canal was begun by Mr. M. Gage in ... and was finished so that water was run through it as ... Arroyo in the fall of 1886. During the winter of ... tunnels were thoroughly cemented on the sides ... depth of from 4 to 6 inches, with Portland cement con-... ...ngs were timbered.

...the work was under the supervision of C. C. Miller, ... R. Gage, as superintendent of construction. On ... W. Irving took charge of the work as engineer, Mr. ... as superintendent of construction.

...part of the year 1887 a temporary connection was ... head of the canal and the river, and water was run ... Riverside in quantities varying from 300 to 500 ...demands of the owners of the land required.

...the canal between the head gates and Ter-... at 2½ feet to the mile, and the total distance ... spring of 1887 a survey of the continuation ...squite Arroyo was made by W. Irving, the ... general location determined on or about ... The grade on which the continuation was ...e mile, or about 0.04 foot to the station.

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[a] ...a Irving, of Riverside, for most of the facts herein ...

A WELL NO. 43 OF GAGE CANAL SYSTEM

B. METHOD OF CAPPING ARTESIAN WELL OF THE GAGE SYSTEM.

On August 1, 1887, the permanent head gates were located and the work of construction was begun. In November, 1887, the water was turned into the canal through the new head gates, which are shown in fig. 3, page 86. In fig. 4, page 87, is shown a section of the headworks.

On August 15, 1887, the work of constructing a submerged dam for the diversion of water to the canal and for carrying the water from the sources on the north side of the river was begun, the dam being completed about the end of November of that year.

In the same year Mr. M. Gage claimed to be the owner of all of the water flowing in Santa Ana River at the point of diversion, which at that time was said would equal, on an average, about 450 miners' inches, or 9 cubic feet per second, during the irrigation months. At the same time Mr. Gage had developed, by means of fourteen artesian wells, about 600 miners' inches, as measured by G. O. Newman, making a total of 1,050 miners' inches, or 21 cubic feet per second. The owners of the Gage canal bought the Camp Carlton ditch, one of the old water rights of Santa Ana River, upon the ownership of which it based in part its claim to the total flow of the river at its headworks. In consideration of this transfer the vender was to receive water from the Gage canal.

At that time Mr. M. Gage was the owner of all of the lands known as the Orange Grove Homestead, amounting to about 2,300 acres and situated in and forming part of the San Bernardino Rancho. Santa Ana River flows through these lands for a distance of about 3½ miles, the course of the river being S. 65° W., on a line passing through points of entrance and exit. The lands described form both banks of the river throughout very nearly its entire course. In consequence, Mr. Gage, as riparian owner, claimed all of the water flowing in the river at that point. About the end of June, 1887, the Riverside Water Company entered suit against him, denying his right to take more than a certain amount of water from the river. The case was tried, and the judgment, which was given in the early part of 1888, limited the amount of water to be taken from the river by Mr. Gage during the irrigation season—including the months of May, June, July, August, and September—to 289.5 miners' inches. Under that decision it is presumed that during the remaining seven months all of the water flowing in the river may be taken out and used by those who can obtain it.

In the spring of 1888 the total available supply to the Gage canal was as follows:

	Miners' inches.
River water	289.5
Parish ditch, say	30.0
From wells	600.0
Total (1887, 1888)	919.5

Or 18.39 cubic feet per second.

During a flood in Santa Ana River in the month of February, 1888, the submerged flume was carried away, and up to the present time it has not been replaced.

In the latter part of 1887 and the early part of 1888 the portion of the canal below Terquisquite Arroyo was finally located, the terminal point being on the SE. ¼ sec. 19, T. 3 S., R. 5 W., S. B. M., 8.26 miles distant from the terminus of the upper section, measured on the line of the canal. This makes a total length of canal equal to 20.16 miles between the head gates and the lower end, or the point above described.

The work of construction on the second or lower section of the canal was begun in the early part of the year 1888, Grant Brothers having the contract for the earth work. Flumes Nos. 9 to 13, inclusive, were constructed by Mr. M. Gage, under the supervision of W. Irving, as engineer, and R. Gage, as superintendent of works, and the whole was practically completed in the early part of August of the same year (1888), except a short interval (about 1,700 feet) through sec. 21, T. 3 S., R. 5 W., S. B. M.

On March 31, 1888, the water was first turned into flume No. 9, over Terquisquite Arroyo, and from thence over to flume No. 10 and into the canal below for a distance of about 600 feet. After that date it was run to section 21, as already described. The amount of water running in the Gage canal during the month of July, 1888, was from 500 to 700 miners' inches, measured at flume No. 3, which was used for the irrigation of lands north of Terquisquite Arroyo, a portion of the water wasting at flume No. 11, Arlington Heights.

During the year 1888, commencing about the month of April, a number of wells were sunk in the river bottom near the point where Mountain View avenue crosses the river. This group of wells was known then and for sometime afterwards as group E. They were eleven in number, including two wells excavated in 1887 a short distance west of the avenue, the remaining nine being located east of the avenue, seven of them on the south side of the river and two on the north side. This group (E) of wells was redesignated in 1892, and they are now known as wells Nos. 28 to 38, inclusive, and form part of a general numbering (1 to 55) of all the wells tributary to the canal. They all are 10 inches in diameter, and at the time of excavation Nos. 28, 29, 33, 34, and 35 gave a very large flow and added greatly to the water supply. The combined flow of the eleven wells equaled 677 miners' inches.

During the year 1888 three additional wells were excavated on the east bank of the canal between flume No. 1 and the point where the Santa Fe Railroad crosses the canal. These wells are 10 inches in diameter. They formerly were known as part of group B, but now are known as Nos. 7, 8, and 9. They have added about 120 miners' inches to the general supply. At the end of the year 1888 the total

water supply available was equal to about 1,500 miners' inches, as follows:

	Miners' inches
Group B (Nos. 7, 8, 9, 11, and 12)	250.0
Group C (Nos. 45, 46, 47, 48, 49, and 50)	258.0
Group D (Nos. 51, 52, 53, and 54)	45.0
Group E (Nos. 28 to 38, inclusive)	582.5
Parish ditch	75.0
River water	289.5
Total	1,500.0

or 30 cubic feet per second.

During the year 1889 the Gage canal below Terquisquite Arroyo was completed in all of its parts and the water was run to the lower end. Improvements all along the line between the head gates and the terminus were made to grade by releveling, cutting, and filling, by increasing the strength of banks in the fills and wherever else needed, and by relining the flumes to grade where they had settled on their foundations.

The maintenance of the canal was under the supervision of Mr. M. Gage, represented by Mr. Irving, as engineer, and the expense was borne by Mr. Gage, excepting the portion between tunnel No. 13 and Terquisquite Arroyo, which was partially borne by the East Riverside Water Company. Many serious breaks occurred during the year 1889, causing several days' interruption in irrigation and considerable expense for repairs.

The total cost of construction of the portion of the canal south of Terquisquite Arroyo, including flumes Nos. 9, 10, 11, 12, and 13, was $30,250.73, as follows: Cuts and fills, $14,849.81; flumes (2,750 feet), $13,900.92; engineering, $1,500. Total length of canal, 8.22 miles.

During the months of June and July, 1889, Mr. E. Low planted to orange trees the greater portion of the south-central 80 acres of sec. 35, T. 2 S., R. 5 W., S. B. M. On this land was used, in 1889, the first water from the Gage canal below flume No. 9 for a useful purpose.

During this and the previous year the lands of Arlington Heights were platted in a most thorough manner by Messrs Whitten and Rawson, under the supervision of Mr. Irving, the street divisions generally inclosing 40 acres and the block thus formed being subdivided into 10-acre lots. All acreage is exclusive of streets.

During the early spring of 1889 one more well was sunk, forming part of group B and now known as No. 10 in the general numbering.

On April 17, 1889, by request of the Home Life Insurance Company, of San Francisco, Prof. E. W. Hilgard, of the University of California, made an examination and measurement of all water flowing or possible to flow at that date from the water sources of the Gage canal. The following are the results of the measurements made while all of the sources were flowing simultaneously and had been flowing for about thirty-six hours. The designation of the wells which was adopted by

Professor Hilgard was the letters A, B, C, and D for certain groups of wells which afterwards were known as B, C, D, and E, the A in the latter enumeration representing the Hunt & Cooley wells, in which Professor Hilgard was not interested. In the following enumeration the latter designation has been adopted, making it agree with all of the other references, to which will be added the present numbering:

	Miners' inches.
Group B, or Nos. 7 to 12, inclusive (6 wells)	260.0
Group C, or Nos. 45 to 50, inclusive (6 wells)	225.0
Group D, or Nos. 51 to 54, inclusive (4 wells)	35.0
Group E, or Nos. 28 to 38, inclusive (11 wells)	571.0
Parish ditch	157.0
South side streams (estimated)	75.0
Water right in Santa Ana River	289.5
Total	1,612.5

On July 27, 1889, by request of the Riverside Water Company Mr. G. O. Newman, representing that company, and Mr. Irving, representing Mr. M. Gage, examined for the first time since the decision of the court was rendered the diversion of water from the river through the Gage canal. They measured the total flow in the canal on the weir at flume No. 3 and determined the net product to be 746 miner inches.

	Miners' inches.
Wells of group E (Nos. 1, 2, 3, 4, 6, 7, and 8, or, according to the present numbering, Nos. 38, 37, 36, 35, 33, 32, and 31) total discharge	320.0
Water right in river	289.5
Parish ditch (estimated)	120.0
Total water flowing at head gate	729.5
Measured water flowing into head gates over weir	594.0
Balance unused	135.5

The difference between the amount of water at the head gates and that at flume No. 3 is accounted for by the discharge of the wells of group B below the head gates. On July 26 or the day previous there was a larger quantity of water discharging into the canal at the head gates, as shown by the following:

	Miners' inches.
Water right in river	289.5
Product of seven wells	300.0
Parish ditch	140.0
Total at lower weir	729.5
Deduct amount at head-gate weir	679.0
Balance unused	50.5

The flow of water in the canal during the year 1889 varied from a maximum of about 800 miners' inches in July to about 500 miners' inches in November.

During the year 1890 many changes and improvements were made in connection with the canal and the lands of Arlington Heights. Mr. Gage had visited England in the fall of 1889, and had interested capitalists in his enterprise of developing the lands at Arlington Heights. In furtherance of the project two representatives, Messrs. T. Waterhouse and Wilson Crewdson, were sent by them to Riverside to examine the property. Their report being favorable a company was formed, the capital stock of which was placed at $1,255,000, divided into 5,000 A shares of $250 each and 1,000 B shares of $5 each. On December 13, 1889, a provisional contract was entered into between Messrs. M. Gage and Wilson Crewdson, which was assigned to the new company, known as the Riverside Trust Company, Limited.

During the early part of the year 1890 pipe lines of riveted steel plate were laid on Adams and Jane streets, and substantial bulkheads were constructed in the canal where the pipe lines entered. A vitrified pipe line similarly connected was laid on Evans street as far as Dufferin avenue. During the fall and winter following the canal was lined with masonry at the lower fill, between Harrison and John streets, and at flumes Nos. 13, 12, 11, 10, and 9. Retaining walls of masonry were also constructed at the ends of all of these flumes, thus removing the woodwork from contact with the clay. In addition to this the fill at Hall's reservoir and Eighth street, north of Terquisquite Arroyo, was lined with masonry and cement plaster.

A portion of the Williams tract lying east of the east and north line of the bluff of Santa Ana River, amounting to about 430 acres, was purchased by the Riverside Trust Company, Limited, in 1890. This purchase extended the frontage on both sides of the river 1 mile farther to the east, thus making a continuous frontage due east-west of 4 miles, or by following the course of river about 4¼ miles.

During the year it was determined to construct a levee on the south side of the river, beginning at the head gates and extending east, and in connection therewith to construct a flume immediately behind it for the conveyance of water from the artesian wells, and if thought necessary to carry therein to the head gates the river water that could be taken out at a higher point. Piles 8 inches by 8 inches by 16 feet were driven at 16-foot intervals on the line determined for the levee, and an embankment of brush and sand was formed behind the piling and connected to it. The flume was placed 50 feet from the face of the levee. It was constructed of cedar framing and sheeting, and was gradually submerged below the surface of the ground as it extended up the river. About 1,000 feet of these works were built during the year, extending upstream from the old head gates.

No official measurement of the water of the Gage canal was made during the year 1890, measurements having been deemed unnecessary because there was not a scarcity of water. Well No. 55 (the Camp well) was excavated during the year, but was not then used as a part

of the canal water supply. Its flow was estimated to be 50 miners' inches.

During the year 1891 pipe lines were placed on Maude, Horace, Washington, Gratton, Irving, Jackson, John, McAllister, and Stuart streets, and laterals from them were run to the lands of Arlington Heights, amounting in the aggregate to more than 1,000 acres. Masonry foundations were built for all of the flumes from No. 9 to No. 13, inclusive, and bulkheads were constructed at the canal for all of the entering pipe lines. Arrangements were made to cement the canal from the head gates to flume No. 6 wherever it had not already been cemented. During the latter part of the year contract therefor was made with Gray Brothers, of San Francisco, and work was begun in December between flumes Nos. 1 and 2. The work consisted of a thorough reconstruction of the canal by a realignment and regrading of all parts, resulting in a more perfect cross section. Plaster three-fourths of an inch thick, composed of one part Portland cement and four parts clean, sharp sand, was applied to all parts of the canal in natural banks; to all parts in made banks and side-hill work the outer slopes were lined with 6-inch masonry and then were plastered with cement. The ends of all flumes were incased in masonry abutments and retaining walls, freeing them from contact with the earth. During that year (1891) about 1,000 acres of land were planted on Arlington Heights. In 1889 an employee of the company was stationed at flume No. 3, whose duty it was to keep in repair the section of the canal along the bluff and to make a daily record of the quantity of water flowing in the canal at flume No. 3.

During the winter of 1890–91 floods carried away a portion of the levee and the casing of the channel behind it. This was owing to obstructions in the channel above the works, causing a diversion of the river which forced it to approach the levee at almost right angles, resulting in the cutting of a passage which exposed the channel behind to the destructive action of the water. During that season wells Nos. 1 to 6 and Nos. 13 to 27, inclusive, were excavated, making in the aggregate 21 additional wells.

The cementing of the canal as far as flume No. 6, as previously determined, was completed during the spring of 1892. In that year pipe lines also were placed on Arlington avenue and on Ana, Mary, Madison, Evans, St. Lawrence, Jefferson, Irving, Monroe, Van Buren, Robert, and Harrison streets, and a large number of laterals were extended from the mains to the lands and connected with the irrigating flumes. Considerable additional land was planted during the year, but not so much as during the previous year. Arrangements were also made to continue the cementing of the canal from the point where it had been completed in the spring to the upper end of flume No. 10, south of Terquisquite Arroyo. Contracts for this work were entered into with Gray Brothers. The work was begun during the *month of* December and continued during the remainder of the winter.

s same year (1892) James Sheddan was made zanjero of the bove flume No. 3, including head gates, artesian wells, and ıd the work of levee construction was carried on with vigor. rt of the levee between the head gates and well No. 39 was ed during the year and was tested by the floods of the follow- ter, with fairly satisfactory results. Wells Nos. 39 to 44, e, were excavated, making 6 additional wells added to the sys- t year.

ovember 11, 1892, careful measurements were begun of the ıter supply of the Gage canal system developed up to that d were continued several days, for the purpose of determining ıctors in connection with the water sources. The chief results marized in the following table:

Artesian wells of Gage canal system, 1892.

No. of well.	Distance apart.	Depth.	Diameter.	Temperature of water.	Pressure.	Capacity.
	Feet.	*Feet.*	*Inches.*	*Degrees.*	*Feet.*	*Miners' inches.*
	0	656	10	75	25	5.00
	1,216	534	10	74	70	32.50
	296	382	10	74	76	29.00
	525	482	10	74	74	41.20
	561	320	10	73	23	3.50
	265	784	10	74	80	45.00
	4,620	196	10	70	11	13.70
	353	190	10	70	11	21.00
	204	142	10	70	11	3.50
	320	148	10	68	12	3.20
	714	141	7	67	28	24.50
	80	181	7	68	29	21.60
	765	426	10	70	16	86.50
	530	472	10	70	17	101.50
	1,680	518	10	64	17	62.50
	190	388	10	66	50	50.00
	175	380	10	65	50	32.00
	480	386	10	62	50	27.00
	330	196	10	62	17	43.50
	270	124	10	62	12	9.50
	260	116	10	62	13	24.70
	270	134	10	62	17	50.50
	265	168	10	62	11	36.00
	265	166	10	62	14	26.00
	320	152	10	62	14	19.70
	280	123	10	62	13	21.00
	320	125	10	62	14	9.00
	280	144	10	62	15	38.00
	310	140	10	62	16	28.30
	790	138	10	62	13	11.20
	430	106	10	64	15	3.70
	35	130	10	64	16	16.20
	315	146	10	63	18	41.00
	550	116	10	63	16	48.00
	130	134	10	63	15	30.50
	120	116	10	64	16	16.00
	680	147	10	66	16	42.00
	90	122	10	66	16	28.75
	276	115	10	66	17	10.50
	1,090	169	10	66	17	77.15
	474	193	10	66	14	63.50
	510	192	10	66	17	85.75
	510	390	10	66	18	109.75
	500	224	10	64	20	92.75
	1,580	123	7	62	25	76.50
	15	133	7	62	25	6.70
	15	133	7	62	25	24.40
	40	139	7	62	25	29.33
	50	211	7	62	23	28.40
	40	100	7	62	25	15.00
	1,500	300	10	64	22	80.00
]						1,793.45

It will be understood that the gagings are minimum measurements taken at the end of the irrigation season and while all of the wells were running open and part of them had been running open during the season. The pressure (in feet) of each well was taken while it was closed. The average flow for each well is 35.15 miners' inches; the total flow is 1,793.45 miners' inches, or 23,243,112 gallons daily.

The work of completing the cementing of the canal was prosecuted during the first three months of the year 1893 and was completed in time for irrigation. Pipe lines were placed on Monroe and Gibson streets and laterals were laid to about 800 additional acres of land. An improved hydrant and hydrant box were adopted—the latter being formed of cement—and attached to all of the irrigation laterals and flumes that were put in during that year; in cases where new boxes were needed elsewhere the improved boxes were placed on the old forms. About 800 additional acres were planted to oranges and lemons during 1893, and arrangements were made during the latter months of that year for the cementing of certain portions of the canal south of flume No. 10 in the same manner as work already done, but the company decided this time to do the work under its own supervision. The work of excavating the channel behind the levee was also carried on, and was completed as far as the finished portion of the levee. The levee was extended up the river about a half mile, or a considerable distance above the adjacent wells. No additional wells were excavated during the year.

In 1894 the work of cementing the canal south of flume No. 10 was proceeded with during the spring months, and about 1,200 feet immediately south of the flume and Arlington avenue were cemented; water service was added to about 200 acres of land, which were planted the same year to orange and lemon trees. The trenching on the south side of the river was continued during the spring of that year, and at a distance of 5,650 feet (1.07 miles) upstream connection was made with the river. The river water owned by the Riverside Trust Company was diverted into this new channel, and the whole supply on the south side of the river, including the wells, was carried through the channel to the head gates. A channel on the north side of the river from the head gates upstream was also commenced and a large portion of it was finished that year.

During the years 1895 to 1898, inclusive, the levee in the river bottom was extended and added to from time to time, until now it extends on both sides of the river a distance of about 2 miles upstream from the original headworks.

WATER SUPPLY.

The water supply of the Gage canal system is, as already stated, largely from artesian wells. During years of drought the supply is wholly from wells. The number of wells has been increased from year to year, as the demand for water grew and as the old wells

became silted up. It is also probable that the extreme drought from 1892 to 1900, coupled with the general increased demand upon this artesian basin, has reduced the flow of the wells. Their maintenance is remarkable, and is one of the numerous evidences of the vast extent of the supply.

The number of wells in the Gage system and their output are as follows:

	Miners' inches.
1887, 14 wells, approximately	600
Fall of 1888, 26 wells	1,135
Spring of 1889, 27 wells	1,091
October, 1892, 55 wells	1,793
June, 1899, 68 wells	1,440

In June, 1899, 55 of the 68 wells were flowing and 13 of them were not flowing. The maximum output is stated by the company to have been 1,440 miners' inches. The company has a right to 289.5 miners' inches at its headworks on Santa Ana River, but during recent dry years this has been of little value. On June 20, 1899, there were at that point 12 miners' inches, and on February 21, 1900, 20 miners' inches. The Parish ditch, which is said to have a normal flow of 120 miners' inches, is now dry.

The sources of water supply to this canal, including the right to develop additional water over an area of 488 acres forming part of a block of water-bearing land, are 2,831 acres, all of which are owned by the company. In 1893 the supply, including river water, was estimated as follows:

	Miners' inches.
Santa Ana River	289.50
Artesian wells, 55 in number, measured at their minimum flow (October 10, 1892)	1,793.45
Parish ditch	20.00
Total	2,102.95

The artesian wells are distributed over a considerable area, but generally extend (for a distance of 15,800 feet) along the canal bank and the river bottom, as shown on the map, Pl. I.

All of the wells were driven by means of a sand pump working inside of a thick, double iron casing or lining, the lining being forced down by means of hydraulic jacks as the pump continued to excavate. The lining is of No. 10 or No. 12 gage iron, in two thicknesses, so that it can be built up and made continuous by inserting inside and outside lengths alternately, each length being 2 feet long and breaking joint in the center. The casing fits so exactly that in a short time the lining becomes, by oxidation, water tight, at least sufficiently so for the purpose.

As already stated, in the spring of 1889 Prof. E. W. Hilgard, of the University of California, made an examination of the artesian water supply of the Gage canal system for the Home Life Insurance Com-

pany, of San Francisco. He was given exceptional opportunities for an exhaustive study, and his report, which is of general interest, is freely quoted from below. He states that the water supply at that time (April, 1889) was as follows:

	Miners' inches.
Supply from 27 wells	1,091
Parish ditch	157
Water right in Santa Ana River	289
South Side ditch (estimated)	75
Total	1,612

On June 30, 1898, there was flowing in the Gage canal at Palm avenue a total of 1,313 miners' inches; on June 20, 1899, 1,273 miners' inches; and on February 21, 1900, 1,129 miners' inches. A reference to the table of rainfall on page 17 will show that the last eight years have been years of unusual drought, and that the season of 1888–89 was in a group of wet years. These wells have, therefore, maintained their supply in the face of the drought and in spite of the fact that the underground gravel reservoir has been heavily drawn upon by other sources. (See general discussion of water supply, page 36.)

The following extracts are made from Professor Hilgard's report:

The bulk of the supply of the Gage Canal is at present from artesian wells, of which there are 42 on the Victoria tract. On the "water tract" proper there are 27 now flowing or ready to flow. These wells are located in four groups, designated by the letters of the alphabet, from A to D. The lettering for these groups of wells is that adopted in the State engineer's report on irrigation in southern California. The difference in the number of wells forming the several groups, and the increased supply of water are due to the boring of additional wells since the State engineer's observations were made.

The wells of each group are separately numbered, in general upstream and counting from south to north. The following data show the number of each group, distances from each other and from the head gate of canal, and the measured flow of each well in miners' inches of 4-inch pressure, the measurement usually adopted in southern California.

GROUP A.

Six wells in line along the canal, the nearest being 2,400 feet from the head gate, and the total distance from No. 1 to No. 6, 1,665 feet.

Measurements of wells in group A.

Number of well.	Distance from well next above.	Diameter of pipe.	Discharge.	Number of well.	Distance from well next above.	Diameter of pipe.	Discharge.
	Feet.	*Inches.*	*Miners' inches.*		*Feet.*	*Inches.*	*Miners' inches.*
1	249	10	36	5	67	7	57
2	304	10	68	6		7	46
3	323	10	35				
4	722	10	18	Total			260

GROUP B.

Six wells occupying an area of somewhat less than an acre (3,900 square feet), istance 1,200 feet from the head gate in a northwest direction; distance from enter of) group C, 3,276 feet.

Measurements of wells in group B.

mber of well.	Distance from well next above.	Diameter of pipe.	Discharge.	Number of well.	Distance from well next above.	Diameter of pipe.	Discharge.
	Feet.	*Inches.*	*Miners' inches.*		*Feet.*	*Inches.*	*Miners' inches.*
.....	15	7	28	5.....	40	7	63
.....	15	7	17	6.....	.....	7	20
.....	40	7	36				
.....	50	7	39	Total.....	.....	.....	225

GROUP C.

Consisting of four weak wells, all with 7-inch pipe, among the first bored, and t as they are at an average depth of about 110 feet on account of difficulties countered in the cobble layer at bottom, for overcoming which suitable tools re not then at hand. The wells are between 10 and 18 feet apart only, and ld from 7 to 12 inches of water each; total, 35 inches. One good 10-inch well uld probably give better results than the four small ones.

This group is distant 4,550 feet northeast from group B and 2,100 feet from the ter of group D. Area actually occupied, 360 square feet.

GROUP D.

This group consists of 11 wells (all with 10-inch pipe), ranging in depth from to 160 feet. Nine are located on the south side of and mostly quite near to the er bed; two are near the north bank, one being in the present bed. The distance between the centers of groups A and B is about 5,800 feet: between D and B, 00 feet. The elevation above group B is about 18 feet; above group A, 31 feet. ea actually occupied by the group, 17 acres.

Measurements of wells in group D.

Number of well.	Distance from well next above.	Discharge.	Number of well.	Distance from well next above.	Discharge.
	Feet.	*Miners' inches.*		*Feet.*	*Miners' inches.*
.....	80	51	8	440	22
.....	687	51	9	.....	37
.....	117	43	10	300	56
.....	139	55	11	.....	74
.....	586	82			
.....	315	65	Total	.....	571
.....	42	35			

All the measurements recorded above correspond to the condition of the wells out thirty-six hours after all had been uncapped and had been running their full eams.

This point is of some importance, because measurements made immediately or n after uncapping a well that has been closed for some time show at first a conerably larger dscharge, evidently due to accumulated pressure, or what might called a "local head," requiring some time to run down to the nominal disarge.

DEGREE OF INTERDEPENDENCE OF WELLS.

The extent to which the discharge of any well or group of wells is influenced by that of others situated at a greater or less distance is a question of great practical interest, since upon the answer depends the aggregate amount of water to be expected from further developments on the "water tract" by boring additional wells. I have tested the point in a variety of ways, the more important being the following:

(1) Well No. 6 in group B has for some time past remained capped, with an inch pipe carrying the water to a dwelling house some 300 yards away, the water reaching the level of 26 feet above the casing when all the other wells of the group are capped. It was found when all the other wells are uncapped the water level at the house falls about 3 feet 7 inches. As stated above, the total flow of the wells of this group is 225 inches; that of No. 6, 20 inches. It is distant only 40 feet from well No. 5, having a flow of 63 inches, and all the rest of the group lie within 130 feet. Yet the measurement shows that the opening or shutting down of a flow of 205 inches, or more than ten times the amount of the flow of No. 6, influences its head to the extent of not quite 14 per cent, or three-quarters of 1 per cent of the total discharge of the group.

(2) Well No. 2 of group D had been steadily running for upward of a year, all the rest of the group, as well as those of groups B and C, being closed. It was then discharging about 61 inches. After nine other wells (Nos. 3 to 11, inclusive) had been uncapped, No. 2 was found to have decreased to 57 inches in the course of about three hours. On opening No. 1, within 80 feet of No. 2, its flow fell off to 55 inches, and forty-eight hours afterwards it had reached its minimum flow of 48.4 inches, which, however, five hours after was found to have risen again to 51 inches, the figure adopted in the table above. Such fluctuations of a few inches appeared of measurements made at different times of the day, in almost all cases of strong flow, possibly as the result of barometric variations or other diurnal causes.

It will be seen that in the case of this well the letting loose of 520 inches of water within an area of 17 acres immediately adjacent caused a decrease of the flow it had when running by itself of only 10 inches, being about one-sixth, or, say, 17 per cent, of its maximum flow when all the rest were closed, or 1¾ per cent of the total discharge of the group. It will be noted that this is very nearly the same ratio as in the case of well No. 6 in group B reported above.

(3) After the wells had all reached a state of sensibly normal discharge, groups C and D, with their aggregate discharge of 606 inches, were shut down about 5 p. m., in order to observe the effect on other groups.

Group B was measured at 10 p. m., and was found to be discharging 211 inches. Six hours before, when all the other wells were still open, the flow was 205 inches, thus showing an increase of 6 inches, possibly caused by the shutting down of an aggregate of 606 inches at the average distance of about a mile. This is a very slight effect at best, being less than 1 per cent of the total amount shut off, or three-fourths of 1 per cent of the total discharge concerned, and less than 3 per cent of the discharge of the five open wells of the group. But the fact that on the morning of the same day these wells stand credited with a discharge of 21[illegible] inches renders it even doubtful that the shutting down of groups C and D caused the observed increase, and that it was not merely due to diurnal variations referred to above and known to exist. Unfortunately my time did not permit of the continuation of the observations so as to settle this point definitely.

(4) On the following day, eighteen hours after the shutting down of all the other groups, representing an aggregate of 831 inches, at an average distance of about 5,000 feet, group A was remeasured. It was found that the discharge of well No. 1 had decreased from 36 to 29 inches, evidently in consequence of being *loaded down with* a quantity of gravel that had slid in from above, the pipe having

sunk below the ground level. In the rest of the group (Nos. 2 to 6) there had been an increase over the discharge observed in the afternoon of the previous day from 224 to 233 inches, a difference of 9 inches in the total discharge of the group, or 4 per cent of its volume, but only a little over a third of 1 per cent of the total discharge concerned.

(5) A striking proof of the relative independence of these wells of one another when situated at reasonable distances apart is found in the "local head," or accumulation of pressure that takes place so soon as an individual well is shut down. When measured immediately after uncapping, a well that has remained closed for some time is found to discharge from 15 to 17 per cent (in the large wells) more than its normal flow, to which it settles down after a lapse of from twenty to thirty hours. This accumulation and slow running down proves conclusively that we have here to do, not with an ordinary hydrostatic column, but with a mass of water so subdivided by the closely packed materials intervening between the vents made by the auger and in the interspaces in which the water is stored that a rapid transmission of pressure is not possible, *and that the laws of hydraulics and friction, rather than those of hydrostatics, must be held to govern the discharge.* Moreover, it proves that hundreds of inches of water discharge bear but a very small ratio to the total supply that lies behind these artesian fountains.

The nature of these materials as disclosed by the auger or sand pump is found to be gravel (ranging from pea size up to cobbles of greater diameter than even the 10-inch pipes), tightly packed with sand of various degrees of fineness. Cobbles nearly filling the pipes—over 7 pounds in weight—have in several instances been ejected by the water pressure from some of these wells. The character of these cobbles can not be mistaken; they represent the same rocks that have been and are now being brought down from the Santa Ana and Mill Creek canyons at the head of the valley, where a wilderness of the same materials (ranging all the way from fine sand up to bowlders of 5 feet in diameter) cover many square miles of surface and are shown in every break of the country. There, as well as in the borings, occasional sheets or strata of clay or other impervious materials alternate with the gravel and cobble deposits, and with the penetration of each such clay layer additional water pressure is obtained in the wells. The sources of Warm Creek, the Parish Ditch, and of such outflows as "Hunt's Spring" doubtless indicate the termination or the perforation from some cause of such impervious water-shedding strata not far from the surface.

On page 23 is an analysis of water from wells in groups A and D of this system.

In October, 1892, the owners of the Gage canal system conducted a series of experiments on 55 artesian wells and obtained results at variance with the previous experiment.[a] The numbers indicated in the first column of the table correspond with numbers on Pl. I and show the locations of the wells. The third column of the table gives the distance to the nearest well, the fourth column the static pressure, in feet, when each well is closed. The fifth column (final measurement, reduced to miners' inches) gives the amount of water that each well was flowing at the end of the experiment, when all of the wells following it in the table were open. For instance, when well No. 115, which corresponds to well No. 1 of the Gage Canal Company's numbering, was open and all of the other wells were closed its discharge was in both instances 5 miners' inches. When well No. 116 was open and

[a] This is probably due to the more complete development of the entire supply by the Gage Canal Company and others.

all of the other wells were closed its discharge was 46 miners' inches; but when all other wells following in the list were open its discharge was 32.5 miners' inches. The seventh column gives the percentage of decrease in the flow of this particular well under the foregoing conditions. The eighth column gives the cumulative number of the original measurement, in miners' inches. In other words, it is the sum of the flow of any well and of all of the wells preceding it in the table, on the basis of one well alone being open. For example, well No. 115 being open and all of the other wells closed, it flows 5 miners' inches. Well No. 116 being open and all of the others closed it flows 46 miners' inches. Then the cumulative number of the original measurement, in miners' inches, corresponding to well No. 116 would be the sum of these two volumes, or 51 miners' inches. The ninth column gives the cumulative number of final measurements, in miners' inches, which is the sum of the discharge, on the basis of the other wells all flowing; as, for instance, in the case of well No. 116, when the other wells are open it would discharge 32.5 miners' inches, which added to the discharge of well No. 115 gives a total for the two wells of 37.5 miners' inches. The tenth column gives the percentage of decrease at each point of comparison between the seventh and eighth columns. The last column of the table gives the temperature of the water.

Fifty-five wells are considered in these experiments, and while the total volume of water obtained increased as more wells were opened, the aggregate flow is not so great, by 52 per cent, as the sum of the flow of all of the individual wells.

From the foregoing it will be seen that in this particular instance a gain was made by boring as many as 55 wells, but it is also indicated that the number of wells could not be increased indefinitely at a financial profit.

Table showing effect of opening and closing neighboring artesian wells of the Gage canal system.[a]

Quadrangle.	New number of well.[b]	Old number of well.	Distance between wells.	Pressure.	Final measurement.	Original measurement.	Difference between original and final measurements.	Cumulative quantity of original measurements.	Cumulative quantity of final measurements.	Decrease in volume.	Temperature of water.
			Feet.	*Feet.*	*Miners' inches.*	*Miners' inches.*	*P. cent.*	*Miners' inches.*	*Miners' inches.*	*P. cent.*	*Degrees.*
San Bernardino	115	1	0	24.75	5.00	5.00	0	5.00	5.00	0	75.0
Do	116	2	1,216	70.40	32.50	46.00	30	51.00	37.50	27	74.0
Do	117	3	296	75.90	29.00	37.00	22	88.00	66.50	24	74.0
Do	118	4	525	73.60	41.25	48.75	15	136.75	107.75	21	74.0
Do	119	5	551	23.00	3.50	3.50	0	140.25	111.25	21	73.0
Do	120	6	265	80.50	45.00	51.75	13	192.00	156.25	19	74.0
Do	121	7	4,620	11.00	13.75	27.50	50	219.50	170.00	23	70.0
Do	122	8	353	11.00	21.00	46.00	55	265.50	191.00	28	70.0
Do	123	9	201	12.50	3.50	9.75	64	275.25	194.50	29	70.0
Do	124	10	321	12.50	3.25	6.00	46	281.25	197.75	30	68.5
Do	125	11	714	28.00	24.50	58.00	58	339.25	222.25	35	67.0

[a] Courtesy of W. Irving, engineer of Gage canal system.
[b] These are the numbers shown on Pl. I.

Table showing effect of opening and closing neighboring artesian wells of the Gage canal system—Continued.

Quadrangle.	Old number of well.	New number of well.	Distance between wells.	Pressure.	Final measurement.	Original measurement.	Difference between original and final measurements.	Cumulative quantity of original measurements.	Cumulative quantity of final measurements.	Decrease in volume.	Temperature of water.
			Feet.	*Lbs.*	*Miners' inches.*	*Miners' inches.*	*P. cent.*	*Miners' inches.*	*Miners' inches.*	*P. cent.*	*Degrees.*
San Bernardino	126	12	80	29.00	21.62	49.75	57	389.00	243.37	37½	8.0
Do	127	13	765	16.10	86.50	150.00	43	539.00	330.37	39	760.0
Do	128	14	530	16.95	101.50	162.00	37	701.00	431.87	39	70.0
Do	129	15	1,680	[a] 17.00	62.50	80.50	23	781.50	494.37	37	64.5
Do	130	16	180	50.60	50.00	60.50	18	842.00	544.37	36	66.0
Do	131	17	175	50.00	32.00	37.50	15	879.50	576.37	35	65.0
Do	132	18	480	[a] 50.00	27.00	71.50	63	951.00	603.37	37	62.0
Do	133	19	330	16.95	43.50	143.00	70	1,094.00	646.87	43	62.0
Do	134	20	270	12.00	9.50	60.00	84	1,154.00	656.37	44	62.0
Do	135	21	260	13.20	24.75	104.00	77	1,258.00	681.12	46	62.0
Do	136	22	270	16.90	50.50	146.00	66	1,404.00	731.62	48	62.0
Redlands	391	23	265	10.90	36.00	132.50	73	1,536.00	767.62	51	62.0
Do	392	24	265	13.80	26.00	68.75	62	1,605.25	793.62	51	62.0
Do	393	25	320	13.80	19.75	68.75	71	1,674.00	813.37	52	62.0
Do	394	26	280	12.60	21.00	75.00	72	1,749.00	834.37	54	62.0
Do	395	27	320	13.80	9.00	34.00	73	1,783.00	843.37	54	62.0
Do	396	28	280	15.00	38.00	88.50	58	1,871.50	881.37	53	62.0
Do	397	29	310	16.10	28.85	47.00	39	1,918.50	910.22	53	62.0
Do	398	30	790	12.60	11.25	30.00	63	1,948.50	921.47	53	62.0
Do	399	31	430	14.90	3.75	9.50	60	1,958.00	925.22	53	64.0
Do	400	32	35	16.10	16.25	28.50	48	1,986.50	941.47	53	64.0
Do	401	33	315	18.40	41.00	90.00	55	2,076.50	982.47	53	63.0
Do	402	34	550	[b]	48.00	98.30	52	2,174.80	1,030.47	53	63.0
Do	403	35	130	15.50	30.50	65.75	54	2,240.55	1,060.97	53	63.0
Do	404	36	120	16.10	16.00	29.50	46	2,270.05	1,076.97	53	64.0
Do	405	37	680	16.00	42.00	92.00	55	2,362.05	1,118.97	54	66.0
Do	406	38	90	16.00	28.75	48.75	41	2,410.80	1,147.72	53	66.0
Do	407	39	279	16.90	10.50	24.75	58	2,435.55	1,158.22	53	66.0
Do	408	40	1,090	16.90	77.15	166.00	53	2,601.55	1,235.37	53	66.0
San Bernardino	155	41	474	13.80	69.50	168.00	58	2,769.55	1,304.87	53	66.0
Do	156	42	510	16.90	85.75	169.00	50	2,938.55	1,390.62	53	66.0
Do	157	43	510	18.00	109.75	137.00	20	3,075.55	1,500.37	52	66.0
Do	158	44	307	20.00	92.75	146.0[illegible]	37	3,221.55	1,593.12	51	64.0
Do	159	45	1,580	25.00	16.50	46.25	60	3,267.80	1,609.62	51	62.0
Do	160	46	15	25.00	6.70	16.75	60	3,284.55	1,616.32	51	62.0
Do	161	47	15	25.00	26.40	66.00	60	3,350.55	1,640.72	52	62.0
Do	162	48	40	25.00	29.33	50.84	60	3,401.39	1,670.05	51	62.0
Do	163	49	50	23.20	26.40	76.00	60	3,477.39	1,698.45	52	62.0
Do	164	50	40	25.00	15.00	[a] 20.00	25	3,497.39	1,713.45	51	62.0
Redlands	409	51	4,440	19.00	00.00	7.00	100	3,504.39	1,713.45	52	64.0
Do	410	52	20	19.00	00.00	7.10	100	3,511.49	1,713.45	52	64.0
Do	411	53	25	19.00	00.00	7.00	100	3,518.49	1,713.45	52	64.0
Do	412	54	25	19.00	00.00	10.50	100	3,528.99	1,713.45	52	65.0
San Bernardino	169	55	5,070	22.00	80.00	150.00	56	3,678.99	1,793.45	52	64.0

[a] Estimated. [b] Left open.

DIVERTING DAM.

The river water is diverted into the canal by means of temporary brush and sand dams, which are renewed each year; but owing to the natural conditions in the river bottom the renewal is a work of small expense compared with the cost of permanent works sufficient to withstand the action of floods, which sometimes exceed 2,000 cubic feet per second over a bed composed of sand and gravel several hundred feet in depth. In a few hours after the river reaches its maximum discharge it recedes to its normal flow, when the whole of it can if necessary be diverted into the canal by throwing up an embankment of sand a few inches above the water surface.

HEAD GATES.

The head gates are strongly constructed of heavy timbers and have three sets of regulating gates, opened by means of ratchets and pin-

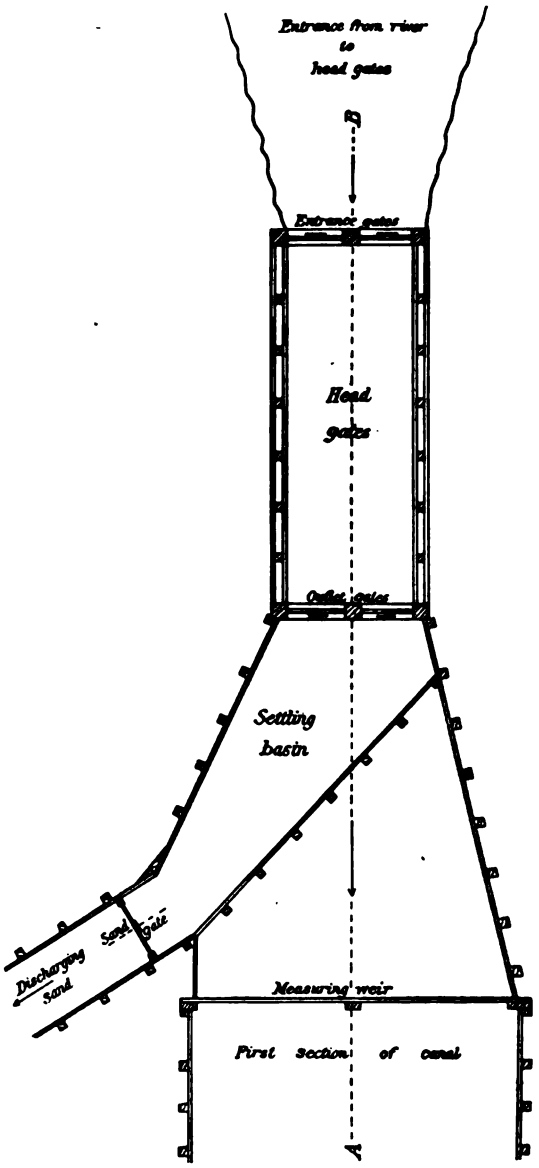


FIG. 3.—Plan showing arrangement of head gates of Gage canal.

ions, one set being sand gates for the discharge of the surplus water and the moving sand. (See fig. 3.)

The water discharges out of the head gates into a settling basin, from which it is measured over a weir into the canal. Figs. 3, 4, and 5 show the head gates and the measuring weir. In connection with the weir there is an automatic register by means of which a record is

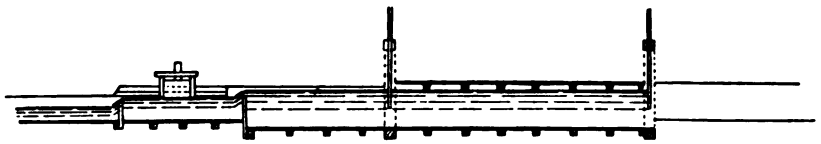


FIG. 4.—Section of headworks of Gage canal, on line A-B of fig. 3.

made of the amount of water flowing into the canal at all times during the irrigation season.

In addition to the automatic register there is an automatic electric alarm by means of which high and low water during the night are

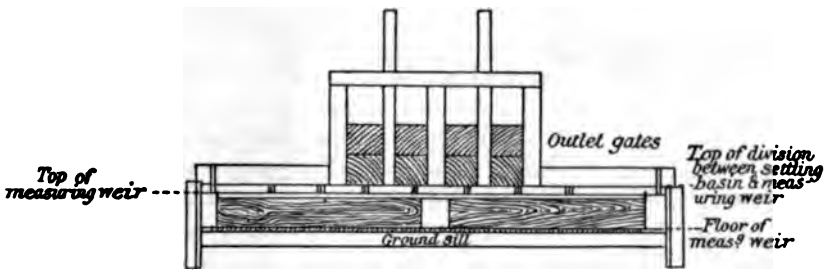

Outlet gates
Top of measuring weir
Top of division between settling basin & measuring weir
Floor of meas^g weir
Ground Sill

FIG. 5.—End elevation of measuring weir on Gage canal, showing end elevation of outlet gates beyond.

made known to the attendant. The cylinder on which the changes are traced receives its motion from a clock movement and makes one revolution in seven days.

The weir over which the water is measured is 23 feet long. The canal at the weir is 24 feet wide and serves as a settling basin for the moving sand, which at times causes trouble. For a distance of a few hundred feet from the head gates the banks of the canal are lined with wooden sheeting, gradually narrowing from a width on the bottom of 24 feet at the head gates to 10 feet where the cemented portion begins. From that point for a distance of 2,950 feet the canal gradually rises from the river bottom proper to the plain of the first mesa lands and to flume No. 1, over a small local arroyo; thence, at a distance of 8,500 feet, through the same mesa lands to flume No. 2, over a small creek; thence, at a distance of 15,650 feet, through the mesa lands to tunnel No. 1 and the base of a range of foothills; thence, at a distance of 21,050 feet, by a series of tunnels and along the face of

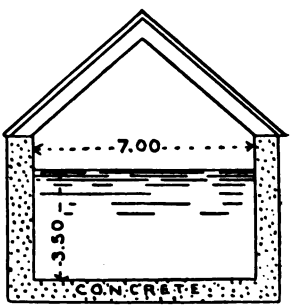


FIG. 6.—Section of tunnel No. 1, in earth, of Gage canal system.

the foothills to flume No. 3. A section of tunnel No. 1 is shown in fig. 6. The canal continues along the bluffs in a series of tunnels, fills, and flumes Nos. 4, 5, and 6 until it passes onto the upper plains at a distance of 27,200 feet. From that point it follows the natural contour of the land, crosses an arroyo by means of flume No. 8 (flume No. 7 being now a fill), and at a distance of 45,600 feet from its head it passes through the projecting point of a foothill by means of a tunnel, and then continues along the natural contour to flume No. 9, over Terquisquite Arroyo, at a distance of 62,800 feet, or 11.9 miles; then, by means of flumes, fills, and cuts, it crosses the arroyo between the foothills and follows the natural contour of the land to the end, the total length being 106,444 feet, or 20.16 miles.

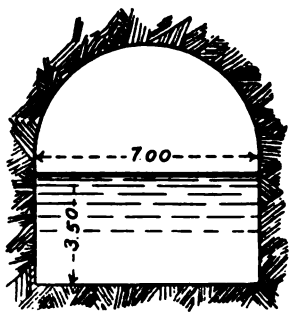


FIG. 7.—Section of tunnel in rock on Gage canal system.

CEMENT LINING.

Generally the slope of the sides of the canal is 4 perpendicular to 3 horizontal.

From the head gates to flume No. 10 the canal is lined with masonry, as are also all tunnels and fills, to a depth of 5 inches, and then is plastered with cement mortar; the remaining portions are lined with cement plaster to a thickness of three-fourths of an inch. Of the whole length of the canal (20.16 miles) 14.5 miles

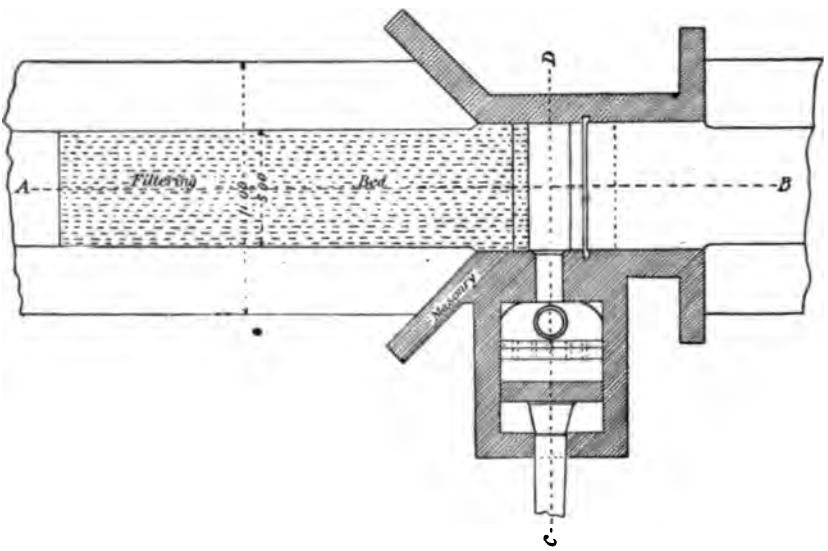


FIG. 8.—Plan of bulkhead and orchard lateral connection on Gage canal system.

are lined with cement. Most of this work was done during the winter months from 1891 to 1894, and at an average cost of $1.50 per foot, or a total cost of $114,135. While it can be said that this cement lining has *not stood well*, it can also be said that it has stood better than was

expected under the conditions. When in increasing the capacity of a channel it is a question of spending $75,000 in one case and $200,000 in the other case, and saving an important percentage of irrigation water, it may be excusable to take some risk. Large surfaces of cement coating three-fourths inch thick can not be expected to stand much strain under the action of storm waters, and it is to this action that nearly all ruptures of the coating are due. Had there been intervals of time during recent dry years to close the canal for repairs

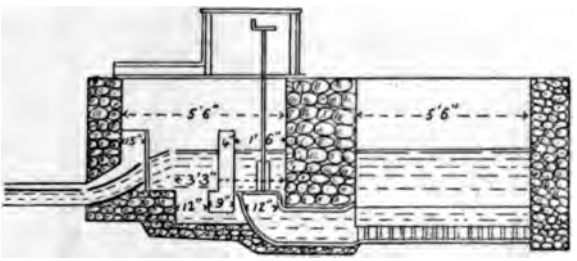


FIG. 9.—Cross section of bulkhead and orchard lateral on Gage canal system, on line C-D of fig. 8.

its condition would be much better. No repairs have been made during the last four years, and the estimated cost of a thorough renovation is less than $1,000, which spread over four years is only a fraction of 1 per cent of the original cost.

The cross section of the canal varies with the distance from the head gates. The bottom width below the head gates is 10 feet, as already stated, which is gradually reduced to 6 feet at flume No. 10; from that point to near the end the width is 5 feet. The canal has a uniform depth of 4 feet throughout its entire length.

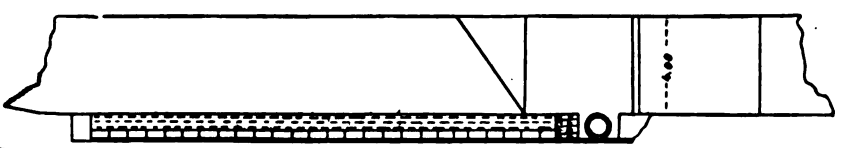


FIG. 10.—Longitudinal section of bulkhead and orchard lateral on Gage canal system, on line A-B of fig. 8.

The total length of tunnels is 5,250 feet. Where they pass through earth formation the bottom and sides are lined with concrete masonry and the roofs are heavily timbered.

The total length of flumes is 4,000 feet. All are strongly framed, rest on masonry foundations, and have retaining walls and foundations at each end where they connect with the other parts of the canal.

CAPACITY.

The capacity of the canal at various localities, as stated by the engineer of the company in 1899, is as follows:

	Miners' inches.
Canal 1.5 miles from headworks	9,646
Tunnel 3 miles from headworks	4,630
Flume 4 miles from headworks	4,270

Min

Weir 5.7 miles from headworks .....
Flume 7.5 miles from headworks .....
Flume 11.9 miles from headworks .....
Canal 12.5 miles from headworks .....
Flume 14.75 miles from headworks .....
Flume 18.5 miles from headworks .....
Pipe line (12-inch) to San Jacinto Land Company from south end of canal .....

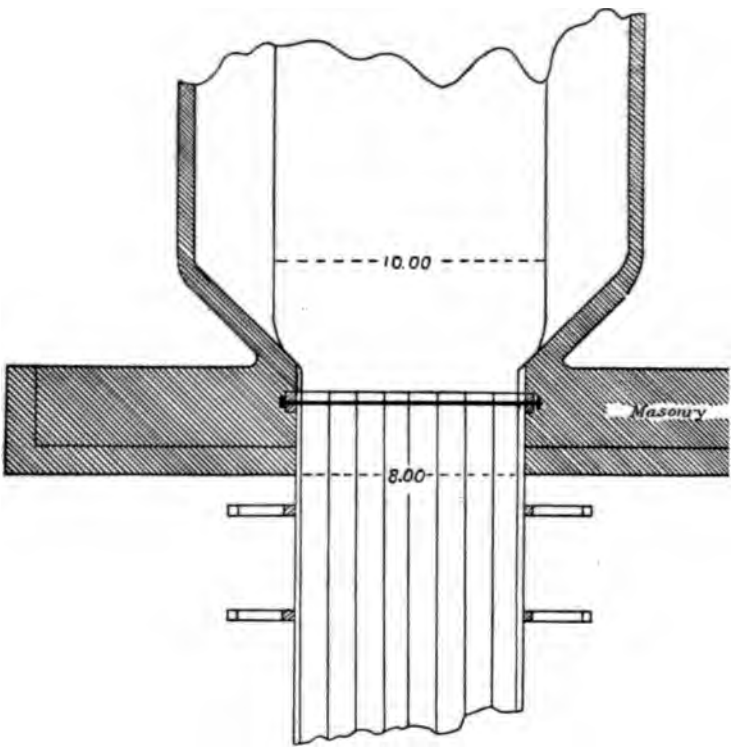


FIG. 11.—Plan showing junction of canal and flume on Gage canal system

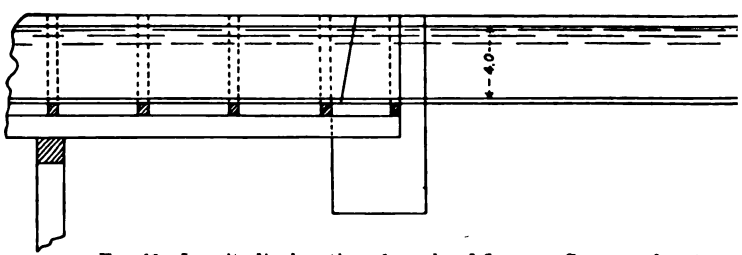


FIG. 12.—Longitudinal section of canal and flume on Gage canal system.

In 1899 the upper section of the canal was carrying 1,440 inches; at the lower end of the middle section there were 742 *inches, while* at the extreme southerly end of the canal the San *Land Company* was taking out through its pipe line, for the s

acres under cultivation, all of the water remaining in the canal, about 106 miners' inches, or 1 miners' inch to each 5 acres. This

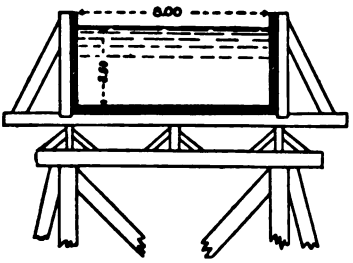
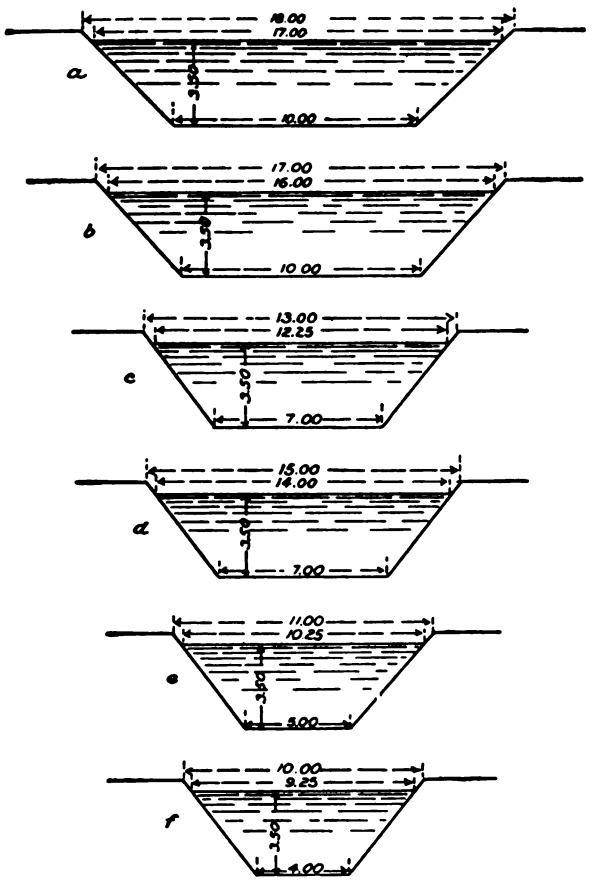


FIG. 13.—Section of flume and trestle on Gage canal system.



14.—Cross sections of Gage canal: *a*, 336 feet from head; *b*, 1.62 miles from head; *c*, 3 miles from head; *d*, 8.55 miles from head; *e*, 18.69 miles from head; *f*, at terminus.

y of 1 inch to 5 acres was then and still is in force on all culti-ɔd lands under the Gage canal. The canal gave nearly the full er supply to its underlying lands during the drought of 1897–1900.

The following table gives the value of the hydraulic elements the various sections of the canal.

Table showing value of hydraulic elements in sections of Gage canal.

	A.	B.	C.	D.	E.	I
Distance from head, in miles	0.064	1.62	3	8.55	18.69	.....
Slope	.000413	.00052	.000683	.000478	.0004	0
Area of cross section, in feet	47.25	45.5	33.25	33.67	26.68	
Perimeter of cross section, in square feet	19.80	19.1	15.60	15.75	13.75	
Hydraulic mean radius	2.38	2.38	2.13	2.13	1.94	
Coefficient of roughness	.014	.014	.014	.014	.014	
Coefficient	121	121	119	119	118	
Discharge, in miners' inches	8,953	9,646	5,635	6,380	4,375	

DIVERSIONS.

East Riverside.—About 30,000 feet from the head gates the f distributing pipe in the East Riverside district connects with canal, and from that point to flume No. 9, over Terquisquite Arro distributing pipes enter the canal at intervals of about one-fou of a mile. Throughout this whole distance metal valves inserted brickwork are provided at all distributing points. (See figs. 8, 9, a 10.) The distribution system is under command of an officer wh duty it is to subdivide the water to the several owners in accorda with their shares and with the by-laws adopted by themselv through their representatives, for its management and distributi Fig. 11 shows the junction of canal and flume generally used on Gage canal system.

The amount of land served by the canal in the East Riverside d trict, extending from the first diversion described to flume No. 9, southerly limit, is 3,620 acres, nearly all of which is now un cultivation.

Lands served by Gage canal in East Riverside district.

	Acres.
Growing oranges	3,000
Growing lemons	40
Growing deciduous fruits	40
Growing alfalfa	40
Total cultivated area	3,120
Uncultivated area	500
Total	3,620

Arlington Heights.—At a distance of 71,900 feet from the he gates, and about 1½ miles from flume No. 9, the lands of Arlingt Heights are reached. These lands are subdivided, by streets, intervals of one-fourth of a mile, each block of about 40 acres bei bounded by streets and the block again subdivided into 10-acre lo

The total acreage served by the canal at Arlington Heights is a ;le more than 4,890 acres, divided as follows:

Lands at Arlington Heights served by Gage canal.

	Acres.
Growing oranges	2,200
Growing lemons	520
Growing grape fruit	170
Total cultivated area	2,890
Uncultivated area	2,000
Total area subject to canal	4,890

Pipe lines.—The distribution of water is by means of steel pipes ried down each street transverse to the canal, with lateral connec- ns to each 10-acre lot, the water being carried to the highest point l furnished with a hydrant and measuring weir. From the hydrants :n flumes are laid along the highest boundaries of the lots, from which water is served to the irrigating furrows between the trees. At end of each pipe line where it enters the canal bulkhead is a ulating valve and a measuring weir. (See figs. 8, 9, and 10.)

The main pipe lines on the streets vary in diameter from 10 inches the canal to 6 inches at the lowest point. The greatest pressure which the pipes are subjected is equal to a head of 164 feet, or 70 nds to the square inch. The pipes are formed of riveted steel te, No. 14 to 18 gage, coated with an asphaltum preparation.

)n the distribution system of Arlington Heights there are 287 lrants, or an average of one hydrant to each 10 acres. The drants are manufactured by the Lacy Manufacturing Company, of s Angeles, from a special design by Mr. William Irving, engineer the Gage canal system. Hydrants are furnished to the irrigators a cost of $10 in place. Over the hydrant is set a cement hydrant t, which is made by the Gage Canal Company and set in place at expense to the irrigators of $10 each, which represents the actual t. In the distribution system of Arlington Heights there are the lowing lengths of steel pipe:

4,800 feet of 12-inch, costing 66 cents per foot laid.
4,000 feet of 10-inch, costing 56 cents per foot laid.
36,500 feet of 8-inch, costing 47 cents per foot laid.
88,400 feet of 6-inch, costing 36 cents per foot laid.
147,200 feet of 4-inch, costing 26 cents per foot laid

This represents a total cost of $92,660 for the pipe in that system.)etailed data pertaining to the distribution system of East River- e under the Gage canal can not be obtained, but the cost, using the ington Heights factor of acreage, which will give results very close he correct figures, would be $102,000. The method of distribution East Riverside lands under the Gage canal is similar to that cribed for Arlington Heights.

San Jacinto Land Company.—The following lands, which are adjacent to the south and west boundaries of Arlington Heights, are served by the Gage canal at its extreme southwesterly terminus:

Lands of San Jacinto Land Company served by Gage canal.

	Acres.
Growing oranges	452
Growing lemons	60
Growing grape fruit	18
Total cultivated area	530
Uncultivated area	120
Total area subject to canal	650

DUTY OF WATER.[a]

The duty of water under the Gage canal system is equal to 1 miners' inch to each 5 acres of land, continuous flow. Its equivalent is 0.02 cubic foot per second, which converted into the form of an equivalent annual rainfall equals very nearly 35 inches depth of water over the whole area of land. As the periods of irrigation are generally at intervals of one month, each monthly irrigation is equal to a rainfall of nearly 3 inches.

Under this system the purchaser of land becomes a shareholder in the canal and the water sources, and by virtue of his water stock has a voice in the management of everything pertaining to the water service. The management consists of a board of directors elected annually by the owners of the lands and the stockholders in the canal company.

The portions of the by-laws which provide for the issuance of stock carrying water rights and for the distribution of the water are as follows:

ARTICLE V.

CAPITAL STOCK.

SEC. 1. The board of directors shall cause to be issued certificates of stock to subscribers or purchasers of stock or to persons with whom the corporation may bargain or contract in relation to the purchase or use of water or water rights or property of any kind or character, and shall cause such stock and certificates thereof to be issued in accordance with the direction of any of the above-named persons; and thereafter shall cause to be issued to stockholders or their assignees certificates of stock, in accordance with law and their articles of incorporation and these by-laws and rights of the parties, which certificates shall be signed by the president and secretary; and all stock (or new stock issued or to be issued in lieu thereof) sold, bartered, or exchanged for the purpose of purchasing water to be supplied to or flowing in the canal or canals used or owned by the corporation shall have attached thereto and transferred therewith and evidenced by indorsement on the certificate thereof a water right or rights to the use of water delivered at the main canal in continuous flow under a 4-inch pressure in the proportion of one-tenth of an inch under said pressure to each share: *Provided*, That the board of directors shall, in their discretion, have power to affix to such water rights when

[a] Detailed descriptions of the use and duty of water under the Gage canal system are given in Bull. 86 U. S. Dept. Agr., office of Experiment Stations, Pt. 1, p. 74, Pt. II, pp. 131-148.

the same are first granted such terms or conditions as to application or use of water for specific purposes as they may contract or see fit, and to provide that such conditions shall be observed, otherwise such water right to be void, but thereafter such terms or conditions shall not be changed except by consent of the stockholder holding such water right: *And provided also*, That such water right shall be subject to the provision of the articles of incorporation in that behalf and to these by-laws or any amendments thereof and to the rules and regulations which are or may be from time to time adopted by the board of directors. Certificates of stock shall not be issued in less amount than one share.

SEC. 2. No transfer of stock shall be binding on the corporation unless duly entered on its books, nor shall stock be issuable until the owner thereof or his duly authorized agent shall have signed a receipt therefor on the stub of the stock-certificate book and until all the previous assessments and water rates as provided by these by-laws and the articles of incorporation, levied thereon according to the law and according to these by-laws and the articles of incorporation, have been fully paid.

ARTICLE VIII.

AS TO BY-LAWS.

These by-laws, or either or any of them, by section or article, may be repealed, amended, or added to, or new by-laws adopted in their stead, either by the stockholders at any meeting thereof or by the majority of the board of directors at any meeting thereof.

ARTICLE IX.

MISCELLANEOUS.

SEC. 1. An inch of water in these by-laws referred to is defined to be a continuous flow of water through an aperture one (1) inch square under a pressure of four (4) inches, measured from the center of such aperture to the surface of the water.

SEC. 2. Each stockholder is entitled to water in continuous flow, or its equivalent, taken monthly, according to the by-laws and regulations of the corporation. Should any stockholder desire to have furnished in one day the supply of water to which he is entitled for a certain number of days not to exceed thirty days (nor in excess of the capacity of the distributing pipe or pipes to his land or lands), he shall give the corporation at least four days' notice of such desire and accept the water on any day or days that the company may be able to arrange for the supply thereof.

COST.

The cost of the system to 1893 is as follows:

Cost of Gage canal system to 1893.

Main canal and connected works, including rights of way	$285,000
Distributing pipe lines and connected works	70,000
Artesian wells	50,000
Water sources and connected lands	175,000
Total	580,000

[For index see end of Part II, Water-Supply and Irrigation Paper No. 60, which contains descriptions of the East Riverside irrigation district, the Riverside-Highland Water Company, and the lower San Bernardino Valley above Rincon, also complete data of the 890 wells in the San Bernardino and Redlands quadrangles, and notes concerning the manufacture of Portland cement in southern California.]

1893.

Seventh Annual Report of the United States Geological Survey, 1885-86, Part II, Papers of an economic character, 1886; octavo, 600 pp.

Contains a paper on the public lands and their water supply, by J. W. Powell. Illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George D. Eldridge, 1894; octavo, 77 pp. Bulletin No. 119 of the United States Geological Survey.

Contains a description of the geologic structure of portions of the Big Horn Range and the Yellowstone Park, especially with reference to the coal fields, and remarks upon the mineral, timber and agricultural resources.

Report of progress of the division of hydrography for the calendar years 1891 and 1892, by F. H. Newell, 1893; octavo, 176 pp. Bulletin No. 101 of the United States Geological Survey.

Contains results of stream measurements at various points, mainly within the Arid region, and records of wells in western Nebraska, western Kansas and eastern Colorado.

1894.

Seventeenth Annual Report of the United States Geological Survey, 1895-96, Part II, Economic geology and hydrography, 1896; octavo, 784 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The underground waters of Illinois," by Frank Leverett, and "Preliminary report on the artesian waters of a portion of the Gulf slope," by R. Hay Taylor.

Artesian well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 366 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 208 pp. Bulletin No. 140 of the United States Geological Survey.

Contains a description of the work done and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896-97, Part IV, Hydrography, 1897; octavo, 730 pp.

Contains "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "Investigations in well boring and irrigation in South Dakota," by N. H. Darton, and "Reservoirs for irrigation," by J. T. Fanning.

1898.

Nineteenth Annual Report of the United States Geological Survey, 1897-98, Part IV, Hydrography, 1898; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1897," by F. H. Newell and others; "The water waters of Ohio," by Edward Orton, and "A preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

Part II of the Nineteenth Annual contains a paper on "Principles and conditions of the movements of ground waters," by I. C. Russ, and one on "Physical investigations in the motion of crystal waters," by C. S. Slichter.

1900.

Twentieth Annual Report of the United States Geological Survey, 1898-99, Part IV, Hydrography, 1900; octavo, 693 pp.

Contains a "Report of progress of stream measurements for the calendar year 1899," by F. H. Newell, and "Hydrography of Nicaragua," by A. P. Davis.

1901.

Twenty-first Annual Report of the United States Geological Survey, 1899-1900, Part IV, Hydrography, 1900; octavo, 738 pp.

Contains a "Report of progress of stream measurements for the calendar year 1900," by F. H. Newell; "Preliminary observations on the geology and water resources of portions of the Black Hills and adjoining regions in South Dakota and Wyoming," by N. H. Darton, and "The Black Hills and their utilization," by W. Lee Darton.

Correspondence should be addressed to

The Director,
United States Geological Survey,
Washington, D. C.

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phoenix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1897.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Underground waters of southeastern Nebraska, by N. H. Darton, 1898.
13. Irrigation systems in Texas, by W. F. Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15, 16. Operations at river stations, 1897, Parts I, II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems of Bitterroot Mountains, by Elwood Mead, 1899.
24, 25. Water resources of the State of New York, Parts I, II, by I. C. Russell, W. Hartel, 1899.
26. Wells of northern Indiana (continuation of No. 21), by Frank Leverett, 1899.
27, 28. Operations at river stations, 1899, Parts I, II, 1900.
29. Wells and windmills in Nebraska, by Erwin Hinckley Barbour, 1900.
30. Water resources of the Lower Peninsula of Michigan, by Alfred C. Lane, 1900.
31. Lower Michigan mineral waters, by Alfred C. Lane, 1900.
32. Water resources of Puerto Rico, by H. M. Wilson, 1900.
33. Storage of water on Gila River, Arizona, by J. B. Lippincott, 1900.
34. Geology and water resources of southeastern South Dakota, by J. E. Todd, 1900.
35–39. Operations at river stations, 1900, Parts I–V, 1901.
40. The Assuan dam, by Thomas U. Taylor, 1900.
41, 42. The windmill: its discovery and use, Parts I, II, by E. C. Murphy, 1901.
43. Conveyance of water in irrigation canals, etc., by Samuel Fortier, 1901.
44. Profiles of rivers, by Henry Gannett, 1901.
45. Water storage on Cache Creek, California, by Alfred R. Chandler, 1901.
46. Rescue of Kern and Yuba rivers, Cal., by W. H. Olin, Jr., and M. Mason, 1901.
47–53. Operations at river stations, 1901, Parts I–VI, 1901.
54, 55. Geology and water resources Nez Perce Co., Idaho, Pts. I, II, by J. B. Lippincott, 1901.
56. Geology and water resources of Yakima Co., Wash., by G. O. Smith, 1902.
57. Methods of stream measurement, 1901.
58. Deep borings in United States, Pt. I, by N. H. Darton, 1902.
59. Water storage on Kings River, California, by J. B. Lippincott, 1902.
60, 61. Development and application of water in southern California, Pts. I, II, by J. B. Lippincott, 1902.

Other papers are in preparation. The endeavor is made to send these pamphlets to persons who have assisted in their preparation by replies to inquiries or otherwise. Requests made for a certain paper are granted whenever practicable, but it is impossible to comply with general demands, such as to have all of the series sent. Application should be made either to members of Congress or to—

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
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UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

EVELOPMENT AND APPLICATION OF WA NEAR SAN BERNARDINO, COLTON AND RIVERSIDE, CAL

PART II

By JOSEPH BARLOW LIPPINCOTT

WASHINGTON
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1902

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DEVELOPMENT AND APPLICATION OF WATER NEAR SAN BERNARDINO, COLTON, AND RIVERSIDE, CAL.

PART II.

By JOSEPH BARLOW LIPPINCOTT.

EAST RIVERSIDE IRRIGATION DISTRICT.

The lands of the East Riverside Irrigation District are 4 miles south of the city of Colton and 4 miles northeast of the city of Riverside. They are divided into approximately equal parts by the boundary line between San Bernardino and Riverside counties, and vary in elevation from about 900 feet to 1,250 feet, being situated on the mesa and bottom lands on the south side of San Bernardino Valley. These lands are specially adapted to the growth of citrus fruits. The district was organized under the Wright irrigation district act, and has had fewer misfortunes than are usual with similar enterprises. It is, however, endeavoring to disorganize. The total area of lands comprised within its boundaries (3,100 acres), 250 acres of which are hilly and rough, being partially unfit for cultivation, leaving 2,850 acres of first-class agricultural land. The irrigation district and its pipe line are shown in Pl. I (Part I). In order to obtain a water supply, in 1892 the irrigation district purchased from Garner & McKenzie 65 acres of artesian lands in the bottoms of Lytle Creek northeast of San Bernardino. Three wells were sunk in these lands, the deepest being 450 feet and the other two about 250 feet each. A cut was also run in the cienaga upon these lands, for the purpose of developing water. The development during that year (1892) produced 100 miners' inches, or 2 second-feet, at a total cost of $5,997. The output of these artesian wells, which are referred to in the description of the wells of San Bernardino Valley, is given in the table on page 36 (Part I).

In 1891 the East Riverside Irrigation District purchased a 24-inch pipe line from Raynor Springs, about 1¾ miles below the artesian land of the district, in sec. 4, T. 1 S., R. 4 W., situated within the district. This pipe line was constructed in the year 1889 by the Vivienda Water Company, for the purpose of serving the greater portion of what is now the East Riverside irrigation district. The pipe is of riveted

iron, the gage ranging from No. 10 to No. 14 Birmingham standard. The maximum pressure per square inch sustained by the different sizes as the pipe was constructed was: No. 14, 30 pounds; No. 12, 71 pounds; No. 10, 110 pounds. The valley hydraulic grade line is 7 feet to the mile, and the discharging capacity 9 cubic feet per second.

After the consummation of the purchase by the district the pipe line was extended 8,100 feet, to the wells that had previously been sunk. The upper portion of the pipe is of steel, No. 14 gage. The reservoir was constructed on the lands purchased. It is 40 feet by 70 feet on the bottom, has a depth of 5 feet, and is cement lined. Two kinds of pipe were used in the distribution system—riveted steel and vitrified clay. In 1892 it was estimated that distribution by this means would cost $15 an acre.

The following are the amounts expended in the construction, with the value of the assets, the purchase of the 24-inch pipe line being included in both statements, which are taken from the report by F. C. Finkle, engineer for the district in 1892:

Expenditures.

Purchase price of Vivienda pipe line	$100,000.00
Extension, 8,100 feet to Vivienda pipe line	23,642.87
Two lateral pipe lines	2,292.10
Reservoir No. 2 (when completed)	1,210.00
Cost of sinking three artesian wells	4,497.00
Drainage cuts to McKenzie Spring	500.00
Total	132,141.97

Value of assets.

24-inch conduit as extended	$123,642.87
Two lateral pipes	2,292.10
Reservoir No. 2	1,210.00
100 inches (2 cubic feet) of water, at $1,000 per inch	100,000.00
Total	227,144.97

The owners of the Vivienda Water Company claim that the pipe line, which they value at $100,000, actually cost $120,160, divided as follows:

Pipe-line material and laying	$96,000
Trenching and back filling	8,000
Right to suspend line on motor bridge	1,000
Bridge across Santa Fe Railroad cut on Third street	360
Engineering and superintendence	3,400
Three miles of cement ditch, including pipe across Little Terquisquite Arroyo	11,400

The cement ditch lines referred to were also transferred to the irrigation district.

RIVERSIDE-HIGHLAND WATER COMPANY.

The Riverside-Highland Water Company is a corporation organized February 21, 1898, under the laws of California, to furnish water for domestic purposes and the irrigation of the lands of shareholders situated in that portion of the East Riverside irrigation district in Riverside County which is known as Highgrove. The capital stock was $200,000, divided into 5,000 shares of $40 each. The policy of the company is to furnish an abundance of water to irrigate 2,500 acres of land at the rate of 1 miners' inch of water measured under a 4-inch pressure for each 5 acres of land for the growing of citrus orchards. Recently the company, by a vote of its stockholders, reduced its capital stock to $100,000, divided into 2,500 shares, of which a little more than 2,300 shares are subscribed for and more than 50 per cent is paid in.

The company is the owner of 157 acres of artesian water-bearing lands a few miles north of Colton, in San Bernardino County, from which the water is conducted in a long underground cement and iron pipe line to the lands of its stockholders at Highgrove, a distance of a little more than 7 miles. On these water-bearing lands there are a number of deep artesian wells, from five of which all of the water now used by the company, amounting to a little more than 300 miners' inches, is pumped by means of one 22-horsepower gas engine and two 30-horsepower electric motors, the electric current being furnished at a cost of 1½ cents per horsepower per hour by the Redlands Electric Light and Power Company. The pumps used are of the centrifugal type.

The company does not know how much water its lands will furnish, but it believes that it has an abundant supply. It is now furnishing sufficient water to meet all the demands of 1,800 acres of both old and young orchards, and so far no one has hesitated on account of lack of water to plant orchards in the territory covered by the company. The water is delivered to consumers on demand upon the payment of a toll of 10 cents per miners' inch for a twenty-four hours' run. The lands watered by the company are at a higher elevation than those watered by any other company in the Riverside district, hence its name. The orchards watered are relatively free from frost.

The East Riverside Irrigation District still exists, with its board of officers, but is not operating its system, the Riverside-Highland Water Company supplying water to such portion of the lands as the owners have become stockholders in its company, also to other lands. The landowners within the East Riverside irrigation district, after an effort of eight years, found it impracticable to carry on the system under the act of the legislature popularly known as the Wright act, owing to the fact that the act provided that the revenue should be raised by annual taxation, and also to the extreme difficulty experienced in collecting the taxes thus levied, resulting in numerous tax sales

and in suits to restrain the execution of tax deeds by the owner just before the expiration of the redemption period. These suits were expensive to the district, in many instances costing more to defend than the taxes were worth when collected, and resulting in vexatious delays and appeals to the higher court. When no redemption was made from tax sales the tax deeds were executed and delivered to the district, which invariably had to become the purchaser, for no private person would venture to purchase at the sales for fear of expensive litigation to protect the titles procured. In this way a large tract of unimproved land owned by divers and sundry persons, both residents and nonresidents, became conveyed to the district, and while the law authorized the district as owner to sell the lands at their market value, no purchaser could be found who was willing to buy them under the titles held by the district. The lands subject to taxation diminished every year to such an extent that it became manifest that the entire revenue of the district for the payment of its obligations—interest on bonds, operating expenses, etc.—would have to be met by the few landowners who were faithful in paying their taxes; hence the landowners, for self-protection, organized the Riverside-Highland Water Company and ceased to operate as the East Riverside Irrigation District.

LOWER SAN BERNARDINO VALLEY ABOVE RINCON.

Santa Ana River is the most important stream of southern California west of the Coast Range. It includes among its tributaries all of the streams entering San Bernardino Valley, and drains a total area above Rincon of 1,463 square miles, including valley lands, exclusive of the lands tributary to Lake Elsinore; 555 square miles of the basin are mountainous. San Bernardino Valley proper contains 525 square miles.[a] There is a secondary coast range lying along the western edge of the valley, through which Santa Ana River cuts a canyon, beginning at Rincon, which is the railroad station of Crary. These hills are of a shale and sandstone formation of more recent geologic origin than the main range to the east, and constitute a dam or dike which concentrates and throws to the surface most of the underflow or seepage water proceeding through the valley toward the sea. This produces a greater volume of water in the river at Rincon during the irrigation season than at any other place along the stream. During the summer there is a larger body of water flowing at Rincon than at any other place in California south of the Tehachapi Mountains, except in Colorado River.

The streams surrounding San Bernardino Valley have drainage basins which are exceedingly steep and are poorly supplied with forest cover. The basin above Rincon is of granite origin. The storms which occur in southern California are frequently violent, and falling on these drainage basins produce torrential floods which rush onto

[a] For details of these drainage areas see Part I, pages 51 and 52.

the plains, carrying large quantities of granitic detritus. In this way San Bernardino Valley has been built up. These great beds of gravel and bowlders have a high percentage of voids, the porous space being probably one-third of the mass. Consequently the floods which are projected upon the plains are rapidly absorbed, and the great underground reservoir, with a controlling outlet at Rincon, the storage capacity of which is very great, is filled.

If an area of gravel of 500 square miles should be charged to a depth of 300 feet its storage capacity would be 32,000,000 acre-feet of water. These figures are given merely to suggest the enormous capacity of this great underground storage reservoir of San Bernardino Valley. It has been charged with waters through a long cycle of years by the floods described. In addition to the winter floods the summer flow of all the streams from San Antonio Creek to Mill Creek is diverted and used for irrigation purposes, and probably 50 per cent of it sinks into the ground and reenforces the water plane. This large underground reservoir slopes toward Santa Ana River, and its surplus waters are brought to the surface in the canyon at Rincon. The velocity with which the water passes through the gravels is undoubtedly very slow and varies with the density of the soil and the steepness of the slope, causing a very constant delivery of water at the Rincon Narrows.

In June, 1898, a series of measurements was made to determine the relation between the water flowing on the surface of the ground at the mouths of the various mountain basins entering San Bernardino Valley and that returning into the channels of the Santa Ana in the central portions of the valley. The following approximate results were obtained:

Discharge measurements in San Bernardino Valley, 1898.

Stream.	June.	September.[a]
	Second-ft.	*Second-ft.*
Mountain streams above Slover Mountain	80	63
Mountain streams below Slover Mountain	21	17
Total summer streams from mountains	101	80
Return and developed water above Slover Mountain	[b]138	[b]145
Return water between Slover Mountain and Riverside Narrows	75	62
Return water between Riverside Narrows and Rincon	61	53
Total return water above Rincon	274	290

[a] Measurements made between August 27 and September 9.
[b] Riverside Water Company's lower canal not included.
NOTE.—One second-foot equals 50 California miners' inches.

From the foregoing table it will be seen that in June, 1898, there were 173 second-feet, or 8,650 miners' inches, and about September 1 180 second-feet more water seeping into the channels of Santa Ana River in the central portion of the valley than there was entering the valley from the mountain drainage basin.[c] The amount of water rising in the central portion of the valley was about three times the amount

[c] For details see page 47, Part I.

that was being furnished from the mountain streams. During the winter season the mountain streams are much larger in volume. In the case of San Gabriel River, in June, 1898, there was a total of 16 second-feet of water entering from mountain drainage basins above Puente, and 62 second-feet were found flowing in The Narrows, where San Gabriel River cuts through the same secondary coast range that the Santa Ana encounters at Rincon. A similar condition exists opposite Tropico, on Los Angeles River, where in June, 1898, there were 68 second-feet of water flowing and no water entering from the surrounding mountain drainage basins.

The amount of water which returns from irrigation into the channel of the Santa Ana below the lands irrigated is known to be large. According to tables which have been prepared by Prof. L. G. Carpenter, in charge of the Colorado experiment station at Fort Collins, Colo., the velocities of underground water are found to be less than 1 mile a year under ordinary conditions. It will therefore require a number of years for return irrigation water which, for instance, is used in the neighborhood of Rialto or Riverside to reach the channel of Santa Ana River. During the summer of 1899 Mr. Cyrus C. Babb, a hydrographer from the United States Geological Survey, made a determination of the amount of water returning from irrigation in the Solomonsville Valley, on Gila River, Arizona, and found that a volume equaling 64 per cent of the amount which was being used for irrigation at that time was returning to the stream; in the neighborhood of Phoenix the amount returning was found, in a similar manner, to be 40 per cent. In Ogden Valley, Utah, on Ogden River, Prof. Samuel Fortier determined, as the result of thirteen measurements made in the summer of 1894, that while the inflow into the valley was 98.9 second-feet the amount used for irrigation was 76.3 second-feet and the outflow was 115.9 second-feet, showing a greater amount returning than was being used at that time for irrigation. This was doubtless due to the fact that greater quantities of water were used for irrigation in the spring than during the summer months. In Colorado, on Cache la Poudre River, Professor Carpenter, as a result of extensive measurements and experiments, has drawn the following general conclusions:

(1) There is a real increase in the volume of the streams as they pass through the irrigated sections.

(2) The inflow is practically the same throughout the year. It is greater in summer and less in winter, principally because of the effect of the temperature on the soil.

(3) The passage of the seepage water through the soil is very slow, so that it may take years for the seepage from the outlying lands to reach the river.

(4) The seepage water is already an important agricultural factor of the State. The capital value of the water thus received in the valley of the Cache la Poudre alone is not less than $300,000, perhaps $500,000, and for the Platte it is from $2,000,000 to $3,000,000. It is large for the other streams, but of unknown amount.

(5) Ultimately the returns from seepage will make the lower portions of such

valleys as the Platte more certain of water and will probably permit a larger acreage to be grown.

(6) The results here shown may be expected to apply, with limitations, to other valleys similarly situated, where irrigation is as copious, crops the same in character, and the subsoil and rock strata similar and at approximately the same inclination. Where the soil is less porous a greater time must elapse for the water to percolate.

At Rincon there is a flat of approximately 4 square miles area immediately above the canyon, which is believed to contain gravel and sand to depths of at least 50 or 60 feet, below which alternate layers of clay and gravel are believed to exist. Approximately one-third of this area lies on the south or left bank of the river and the remaining two-thirds on the north bank.

Numerous measurements have been made from the Riverside Narrows through to Olive, and the maximum volume of water that occurs at any point in the river is believed to be at the wagon-road crossing of the stream near Rincon.

In the following table is given a series of measurements made by the United States Geological Survey approximately 1 mile below the railroad bridge crossing Santa Ana River below Rincon, the measurements having been made at that point until September 29, 1899, since which date they have been made at the wagon bridge. On September 13, 1899, it was found that when there were 74.38 second-feet of water at the Geological Survey gaging station there were 76.61 second-feet of water at the wagon bridge, or 2.23 feet more water at the wagon bridge than at the Geological Survey station. The wagon bridge being the point of maximum flow, subsequent measurements were made there.

Discharge measurements of Santa Ana River and canal near Rincon, below the mouth of Chino Creek.

Date.	Hydrographer.	Discharge of river.	Discharge of canal.	Total discharge.
1898.		*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
June 21	F. H. Omsted	79.81	3.18	82.99
1899.				
January 3	S. G. Bennett	209.40	2.30	211.70
January 16	F. Rolfe	231.90	0.00	231.90
January 28	....do	216.00	6.50	222.50
February 15	....do	181.00	1.75	182.75
March 4	....do	108.60	0.00	108.60
March 18	....do	199.89	0.00	199.89
April 6	....do	172.23	0.00	172.23
April 18	....do	101.10	2.75	103.85
May 2	....do	100.34	2.45	102.79
May 15	....do	100.36	3.95	104.31
June 3	....do	110.27	3.18	113.45
June 16	S. G. Bennett	87.89	1.65	89.54
July 4	F. Rolfe	68.89	2.42	71.31
July 18	....do	64.13	1.54	65.67
August 1	....do	57.82	3.44	61.26
August 15	....do	64.71	3.16	67.87
August 30	S. G. Bennett	65.90	2.00	67.90
September 13	J. B. Lippincott	72.73	1.65	74.38
September 29	F. Rolfe	83.82	0.00	83.82

Discharge measurements of Santa Ana River at wagon bridge above the mouth of Chino Creek.

Date.	Hydrographer.	River.	Chino Creek.	Springs.	Total discharge.
1899.		*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
October 25	J. B. Lippincott	131.32	14.52	0.50	146.34
October 26	do	146.53	14.52	0.50	161.55

Discharge measurements of Santa Ana River at Riverside Narrows, below all Riverside diversions and north of Arlington Heights.

Date.	Hydrographer.	Discharge.
1898.		*Sec.-ft.*
June 20	F. H. Olmsted	47.63
August 29	do	39.05
1899.		
July 17	F. Rolfe	31.70
September 12	J. B. Lippincott	39.69

For the purpose of comparison four measurements of the amounts of water flowing at Rincon and at the division box of the Santa Ana and Anaheim irrigation companies were made on the same dates, with the results shown in the following table:

Discharge measurements of Santa Ana River.

Date.	Hydrographer.	U. S. G. S. gaging station below Rincon.	Division box of Santa Ana and Anaheim irrigation companies.
1898.		*Sec.-ft.*	*Sec.-ft.*
June 21	F. H. Olmsted	79.81	67.47
1899.			
August 30	S. G. Bennett	65.90	59.62
September 13	J. B. Lippincott	72.73	71.68
October 25	do	[a]146.34	144.72
Total discharge		364.78	343.49

[a] Measured at Rincon wagon bridge.

At the time of the first three measurements there was flowing in a ditch on the left bank of the river opposite the gaging station 3.18, 2, and 1.65 second-feet of water, respectively, which is not included in the totals given in the foregoing table. If included it would show a still greater quantity of water at Rincon. The average of the measurements indicates the presence of 5.32 second-feet (266 miners' inches) more water at Rincon than at the division box. If the greater amount of water found at the Rincon wagon bridge, as compared with that at the original gaging station, is considered, as well as the diversions of the ditch on the left bank opposite the original *gaging station*, then it is shown by these measurements that there is

a loss of fully 8 second-feet between the Rincon wagon bridge and the division box of the Santa Ana and Anaheim water companies. On September 13, 1899, there were at the Rincon bridge 76.61 second-feet of water, while in the two canals of the Santa Ana and Anaheim companies, at a point opposite Esperanza Siding and above all irrigation from either canal, there were only 58.68 second-feet of water, showing a loss of 17.93 second-feet (896 miners' inches) between those points. On October 26, 1899, there were 161.55 second-feet of water at the Rincon bridge and 122.37 second-feet in the canals and river opposite Esperanza, the total amount in the canals being 73.21 second-feet. This shows a loss of 39.18 second-feet (1,959 miners' inches). These measurements are not given as absolute, but they were the best possible determinations under existing conditions. The fact that a loss is shown by each of the observers mentioned is considered evidence that a loss exists and that it is large. Additional measurements are desirable in order to determine more definitely the amount of this loss.

An examination of the wells in the vicinity of Rincon was made in connection with the investigation. As a result it is believed that a bed of gravel, cobble, and sand 40 feet deep exists on the south side of the river, that it is porous and filled with water, and that development works of proper size and form could obtain from it a large supply. From the Auburndale bridge to the Rincon bridge the river gains 12.75 second-feet of water, as indicated by the measurements of September, 1899, Chino Creek not being considered. An examination of the records of wells north of the river indicates that a blanket of clay slopes from the neighborhood of Chino toward the south. Artesian wells occur in the neighborhood of Chino, and flowing water is obtained as far south as the Pioneer schoolhouse, which is approximately 3 miles north of the land referred to. In a well on the property of Mr. Durkee, approximately 1 mile north of this land, a blanket of hard clay 20 feet thick was encountered at a depth of 47.5 feet from the surface of the ground. Beneath this was coarse gravel. The water in this well rose to within a few feet of the surface of the ground. The well furnishes a supply which has never been exhausted by the demands upon it.

Mr. Durkee states that similar conditions were encountered at the schoolhouse well. From the Auburndale bridge to Chino Creek springs are found on both sides of the valley. The evidence obtained from the wells indicates that a blanket of clay may be found in the gravel beds near Rincon. If this layer of clay exists, beneath it will be found large bodies of water, which can be pumped extensively if they do not flow naturally, and the water supply be increased thereby. The only evidence to the contrary that was found was at the pipe works, approximately 3 miles southeast of Rincon, where indefinite information was obtained that two wells have been put down, one 500

and the other 600 feet in depth, through sandstone, bowlders, and gravel, without encountering a layer of clay. The water in these wells, however, rose to within 25 feet of the surface, and the supply has been found sufficient to meet all demands upon it. The elevation of these wells at the surface of the ground is approximately 100 feet above the river at Rincon. At the foot of the small mesa which immediately joins the town on the south shallow wells have been put down to a depth of 25 or more feet, from which flowing water has been obtained.

If development works can be located which will permit the lowering of the water plane 21 feet beneath the surface of the ground, where it now stands, over an area of 1,000 acres, sufficient water could be obtained to furnish 1,000 miners' inches for a period of six months. It has previously been shown that there enters the river naturally from the eastern end of the valley to the Rincon bridge, inclusive of Chino Creek, approximately 700 miners' inches. This increase indicates a supply which is constantly approaching these lands and which should be an addition to the storage capacity of the gravel mentioned. It is believed, therefore, that from 1,500 to 2,000 miners' inches of water could be obtained if development works were constructed which would permit the lowering of this water plane each season 21 feet over an area of 1,000 acres. In a gravel bed west of Burbank the West Los Angeles Water Company has constructed a cut approximately 3,000 feet in length, which varies in depth from nothing to about 25 feet, and which is now delivering, at the end of the drought of 1900, in the neighborhood of 300 miners' inches of water in a locality which is not so favorably situated for the purposes of developing water as are the lands referred to. The works of the West Los Angeles Water Company consist of an open cut in which is placed a wooden flume with sides and top but without bottom. The water enters the flume principally through the bottom. These development works have been in operation since the fall of 1895 and have maintained a continuous discharge of water, although the water plane of San Fernando Valley has been steadily falling.

The Crystal Springs Water Company has laid approximately 2,000 feet of sewer pipe, with open joints, in the sandy bed of Los Angeles River in the narrows west of Verdugo. There are four pipes, laid in two cuts, which are collecting from 400 to 500 miners' inches of water from the river bottoms.

Broadly speaking, the method of procedure should be to divert the entire flow of Santa Ana River near the Auburndale bridge at the beginning of the irrigation season, say the first of May, and carry it in a lined conduit to a point west of Rincon where a drop could be obtained which would produce a substantial water power. The water stored in the gravel beds should then be drawn down by means of pumps operated by this power. At the end of the irrigation season

the pumps could be stopped and the water be returned to the natural bed of the river between the Auburndale bridge and Rincon during the season of the year when the supply is large and when the loss to the river in recharging these beds, in addition to the natural inflow of water returning from irrigation, would not be felt. In this manner the storage capacity of the gravel beds would be available the following spring, when the water plane could again be drawn down. Any artesian water that might be found would be in addition to the water obtained from the pumps.

Summarizing, the following conclusions have been reached:

(1) That a large percentage of water used for irrigation returns to the channels of the streams, the amount being greater where the soil is porous and the slopes are steep, both of which conditions exist in San Bernardino Valley.

(2) That the movement of the water through the soil is exceedingly slow, and that while the increase due to irrigation is now felt at Rincon the volume of return water from irrigation will increase in the future and will be a permanent source of supply.

(3) Water of this character is now making its appearance on the lands near Rincon. This is indicated by the fact that although we are now practically at the end of a nine-years' drought the water plane of these lands has steadily risen, until orchards, vineyards, and alfalfa fields which are said to have previously flourished have been drowned. Around Riverside alone 5,000 miners' inches (100 second-feet) of water are now being used for irrigation.

(4) It is impossible to determine accurately the amount of water that could be gathered. It is believed, however, that about 2,000 miners' inches or more could be obtained by pumping. This amount would be independent of any supply which would be obtained from artesian wells.

(5) That the stream measurements show a loss between Rincon and the head of the Santa Ana canal near Esperanza of about 800 miners' inches, which might be saved by a lined conduit extending down the canyon about 7.4 miles.

WELLS IN REDLANDS AND SAN BERNARDINO QUADRANGLES.

All of the wells in the Redlands and San Bernardino quadrangles, irrespective of size or producing capacity, were visited by representatives of the Geological Survey during the summer of 1900. There were 412 wells in the Redlands quadrangle, which were inspected by Mr. Louis Mesmer, of Los Angeles, and 478 wells in the San Bernardino quadrangle, which were inspected by Mr. C. J. Roney, of the same city. The results of the observations were described with considerable detail in the field record books, but have been condensed for publication in this report and are given in the following tables. The

No. of well	Owner	Location (T. R. S.)			Year completed	Class of well	Elevation of surface	Elevation of water	Depth of well	Strata	Quality of water	Method of lift	Cost of well	Cost of machinery	Quantity of water	Use of water
		S.	W.				Feet.	Feet.	Feet.						Sec.-ft.	
1	Dr. Meeker	1	2	16	1900	D, 4 by 6 feet	1,995	1,718	180	CG			$1,100			
2	Ward, Mills & Co	1	2	21	1900	D, 4 by 6 feet	2,005	1,933	125	CG		Gas	750			
3	Crafton Water Co	1	1	7	1900	D, 5 by 6 feet	3,010	2,992	132	BG		Centrifugal; electric	2,000	$2,500	1.38	Irr; power.
4	do	1	1	8	1900	D, 5½ by 6½ feet	3,650	3,648	93	GR		do	[a] 6,000	2,500	2.70	Irr; power.
5	Mrs. M. A. Brown	1	2	22	1879	D, 4 by 4 feet	2,250	2,225	27	Gravel	Hard	Wind		100		Dom.
6	Geo. McIntosh	1	2	22	1899	D, 4 by 4 feet	2,230	2,189	70	Gravel		Centrifugal; electric				Irr.
7	R. P. McIntosh	1	2	29	1900	D, 4½ by 4½ feet	1,910	1,818	103	SGB	Soft	Cylinder pump; gas	700	925	0.14	Irr.
8	L. Lodge	1	2	16	1900	D, 4 by 6 feet	2,060	2,050	70		do	do		1,500	0.30	Irr.
9	L. Lyons	1	2	16	1900	D, 4 by 6 feet	2,075	2,052		GB		do				Irr.
10	T. P. Christian	1	2	17	1900	D, 4 by 6 feet	1,900	1,748	180	CBSG	Soft	do		1,500		Irr.
11	F. Wieder	1	2	29	1900	D, 4 by 5 feet	1,830	1,779	100	GBC	do	do	450	950		Irr.
12	E. J. Roberts	1	2	28	[b]	D, 4 by 6 feet	2,200	2,192				Horse	300			Irr.
13	H. H. Garstin	1	2	29	1900	B, 10 inches	2,000	1,905	241	CG	Soft	Cylinder pump; gas	800	1,430	0.06	Irr.
14	W. J. Tench	1	2	19		D, 4 by 6 feet	1,720	1,560	163	SGB						Irr; dom
15	East Redlands Water Co.	1	3	36	1900	B, 12 inches	1,805	1,621	514			Cylinder pump; gas	2,200		0.32	Irr.
16	E. & D. Conkling	1	2	31	1899	B, 10 inches	1,795	1,545	350		Hard	do		2,200	0.40	Irr.
17	M. S. Crosswell	1	3	24		D, 4 by 6 feet	1,540	1,378	163	Gravel	Soft	do			0.12	Irr.
18		1	2	33		D, 2½ by 4 feet	2,120	2,060	60							
19	Mr. Gregory	1	2	33	1892	D	2,130	2,123	10			Hand	20			Dom.
20	Dunlap estate	2	2	4	1899	B, 10 inches	2,040	2,040				Centrifugal; gas			0.50	Irr.
21	do	2	2	4	1895	B, 7 inches	2,075	2,077	142			Artesian			0.005	Dom.
22	do	2	2	4	1900	B, 10 inches	2,100	2,100	800	CGS	Hard	do	2,950		0.015	Irr.
23	do	2	2	4	1900	B, 10 inches	2,090	2,090		CSG	do	do				Irr.
24	Houghton & McNee	2	2	4	1895	D, 3 by 4 feet	2,270	2,227	43	Gravel		Wind				Dom.
25	Geo. Clyde (tunnel)	1	2	26		H, 4 by 6 feet	2,700	2,700	97	Porphyry		Gravity	[c] 300		0.02	Irr; dom.
26	Mr. Biggin	1	2	34	1899	D, 6 by 6 feet	2,224	2,163	65	SG					0.16	
27	South Mountain Water Co.	1	2	33	1900	B, 10 inches	2,160	2,132	200+			Centrifugal; steam				Irr.
28	Garland estate	1	3	25	1900	B, 10 inches	1,570	1,394		CG		Cylinder pump; gas				Irr.
29	C. D. Fowler	1	3	5	1891	B, 10 inches	1,180	1,125	70	SG	Hard					
30	West Redlands Water Co.	1	3	35	1899	B, 12 inches	1,600	1,580	226	GCB	do	Cylinder pump; gas	1,250	2,500	0.40	Irr.
31	do	1	3	35	1899	B, 10 inches	1,620	1,529	248	GCB			1,080			Irr.
32	do	1	3	35	1899	B, 12 inches	1,628	1,536	243	GCS		Cylinder pump; gas	1,700	2,500	0.36	Irr.
33	Redlands Heights Water Co.	2	3	1	1900	B, 10 inches	1,880		300	CSG			1,200			Irr.
34	Mr. Painter (?)	2	2	8	1899	D, 4 by 6 feet	1,975	1,932	60	Gravel						
35	do	2	2	8	1899	D, 4 by 6 feet	1,975	1,932	46	Gravel						

[a] Well and tunnel 250 feet long.

[b] Not completed.

[c] Tunnel 97 feet long.

Wells in Redlands quadrangle—Continued.

No. of well.	Owner.	Location (T. R. S.).			Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S.	W.				Feet.	Feet.	Feet.						Sec.-ft.	
36	Mrs. Diaz	2	3	14	.....	B, 7 inches	1,545	1,456	96	.....	.....	Hand	$125	$20	.....	Dom.
37	C. W. Blue	2	3	14	1898	B, 7 inches	1,523	1,455	110	Gravel	Hard	Wind	200	75	.....	Dom; irr.
38	A. Gregory	1	3	27	1895	B, 7 inches	1,379	1,274	168	CRGS	do	do	250	500	0.016	Dom.
39	W. McConkey	1	3	27	1898	B, 7 inches	1,380	.....	.....	.....	.....	do	.....	.....	.....	Dom.
40	D. Madell	1	3	27	1898	B, 7 inches	1,377	1,277	171	.....	Hard	do	274	.....	0.001	Dom.
41	G. H. Garland	1	3	26	1899	B, 10 inches	1,450	1,261	246	GC	.....	Cylinder pump; gas.	.....	3,000	0.40	Irr.
42	C. L. Hayes	1	3	27	1899	B, 10 inches	1,420	1,270	428	CGSB	Soft	do	850	1,400	0.30	Irr.
43	O. W. Harris	1	3	34	1895	B, 7 inches	1,503	1,303	312	CSG	Hard	Cylinder pump; electric.	600	800	0.075	Irr; dom.
44	Horace Evans	1	3	33	1899	B, 10 inches	1,455	1,259	660	CG	Soft	Cylinder pump; gas.	1,900	1,400	0.18	Irr; dom.
45	A. C. Fowler	1	3	32	1898	B, 9 inches	1,250	1,140	170	SGC	do	do	250	300	0.10	Irr.
46	L. C. Smith	1	3	32	1898	D, 3 by 3 feet	1,215	1,135	83	Gravel	Hard	Wind	90	65	0.003	Dom.
47	P. B. Fussell	1	3	32	1897	B, 12 inches	1,253	1,195	165	SGC	Soft	do	330	220	.....	Irr; dom.
48	E. Vaché	1	3	32	1885	B, 7 inches	1,260	1,200	140	.....	Hard	do	170	75	.....	Dom.
49	.....	2	3	4	1893	B, 7 inches	1,350	1,200	150	.....	.....	do	.....	.....	.....	St.
50	W. D. Covington	2	3	4	1893	B, 7 inches	1,325	1,200	157	.....	Hard	Hand	350	20	Small.	St.
51	do	2	3	4	1893	B, 10 inches	1,300	1,300	750	.....	do	Artesian	2,000	.....	0.002	Dom; st.
52	D. S. Jordon	2	3	4	1899	B, 7 inches	1,395	1,379	56	LSGC	do	Wind	80	90	0.001	Dom; irr.
53	Redlands Domestic Water Co.	1	3	35	1899	B, 10 inches	1,560	1,503	.....	CSG	do	Centrifugal; electric.	1,800	.....	0.80	Dom; irr.
54	Wood, Bill & Davis		3	33	1899	B, 10 inches	1,305	1,225	462	CGS	Soft	Cylinder pump; gas.	1,200	1,800	0.40	Dom; irr.
55	D. H. Gillan		3	32	1899	B, 8 inches	1,245	1,157	438	.....	do	Air compressor; gas.	.....	3,000	0.50	Dom; irr.
56	H. Bermudas		3	32	1893	B, 7 inches	1,210	1,156	112	.....	Hard	Hand	.....	3	.....	Dom.
57	N. B. Hinckley estate		3	32	.....	B, 10 inches	1,177	1,021	700+	.....	.....	Wind	.....	.....	.....	Dom; irr.
58	Wm. Curtis		3	30	1885	B, 10 inches	1,144	1,076	76	.....	Hard	do	150	100	0.002	Dom.
59	E. C. Curtis	1	3	29	1895	B, 7 inches	1,120	1,070	96	.....	do	do	160	75	0.002	Dom.
60	R. T. Curtis	1	3	29	1895	B, 7 inches	1,123	1,073	86	GC	do	do	140	100	0.003	Dom.
61	W. M. Curtis	1	3	29	1899	B, 12 inches	1,125	1,079	415	CG	Soft	Cylinder pump; gas.	900	1,800	0.70	Irr.
62	N. B. Curtis	1	3	29	1895	B, 7 inches	1,126	1,076	84	.....	Hard	Wind	140	60	0.001	Dom.
63	N. B. Hinckley estate	1	3	30	1899	B, 36 inches B, 11 inches	1,150	1,103	65 271	Gravel	do	Centrifugal; gas.	900	800	0.42	Irr.
64	L. & M. Frink	1	3	30	1889	B, 7 inches	1,140	1,112	62	LSGC	do	Wind	100	163	.....	Dom.
65	Mrs. P. S. Stewart	1	3	30	1898	B, 7 inches	1,144	1,109	76	CG	do	do	150	65	0.001	Dom.
66	Gansnor & Renwick	1	3	30	1898	B, 7 inches	1,140	1,110	200	.....	Soft	do	320	90	0.003	Dom; irr.
67	Redlands Water Co.	1	3	35	1899	B, 10 inches	1,563	.....	.....	.....	Hard	Centrifugal; electric.	.....	.....	.....	Irr.
68	Mrs. M. Robison	1	3	30	1870	D, 3 feet	1,110	.....	24	.....	do	Hand	.....	.....	Dry.	.....
69	Southern Pacific R. R. Co.	1	3	31	1890	B, 7 inches	1,176	1,116	75	.....	do	do	145	20	.....	Dom.
70	W. F. Whittier	1	3	31	1898	B, 10 inches B, 7 inches	1,410	1,208	204 212	LCG	Soft	Cylinder pump; gas.	1,000	935	0.14	Dom; irr

71	.....do.....	1	3	31	1898	B, 14 inches ..... B, 10 inches	1,150	1,108	276 84	Gravel.....	...do..	Force pump; gas	1,080	.....	0.80	Irr.
72	Owen Buchanan.....	1	3	31	1898	B, 7 inches	1,265	1,149	237	LSGC.....	...do..	Cylinder pump; gas.	379	800	0.14	Irr.
73	W. J. Lawrence.....	1	3	31	1898	B, 7 inches	1,260	1,143	190	LCG.....	...do..	.....do.....	304	700	0.12	Irr.
74	Frink Bros.....	1	3	30	1899	B, 36 inches ..... B, 10 inches	1,147	1,105	335	.....	Hard.	Centrifugal; gas.....	800	700	0.62	Irr.
75	Rhoda Wilson.....	1	3	30	1899	B, 7 inches	1,138	.....	59	CG.....	...do..	Wind.....	95	65	0.001	Dom.
76	D. Van Leuven.....	1	3	30	1900	B, 9 inches	1,132	1,098	63	.....	...do..	Hand.....	65	14	.....	Dom.
77	E. Hankins.....	1	3	28	1899	B, 12 inches	1,254	1,200	200	Gravel.....	...do..	Cylinder pump; gas.	800	1,800	0.40	Irr; dom.
78	J. A. Osborn.....	1	3	28	1899	B, 10 inches	1,225	1,173	320	LGC.....	...do..	Centrifugal; gas.....	880	.....	0.50	Irr; dom.
79	.....do.....	1	3	28	.....	B, 7 inches	1,224	1,174	190	LGC.....	...do..	Wind.....	300	72	0.001	Dom.
80	Mrs. S. W. Sylvera...	1	3	29	1891	B, 7 inches	1,200	1,170	90	.....	.....	.....do.....	.....	80	0.001	Dom.
81	A. B. Cook.....	1	3	29	1897	B, 10 inches	1,206	1,166	110	LSG.....	Soft..	Centrifugal; gas.....	220	800	0.40	Dom; irr.
82	S. Mansfield.....	1	3	29	1900	B, 10 inches	1,195	1,163	340	Gravel.....	.....	.....	.....	.....	.....	.....
83	.....do.....	1	3	29	1890	B, 7 inches	1,193	1,154	109	.....	Hard.	Wind.....	175	.....	Small.	Dom; irr.
84	A. Lenanon.....	1	3	29	1895	B, 7 inches	1,186	1,156	130	.....	...do..	Cylinder pump; horse	208	40	.....	Dom.
85	John Furney.....	1	3	29	1890	B, 7 inches	1,179	1,139	60	.....	...do..	Wind.....	100	150	0.008	Dom; irr.
86	Barton Land and Water Co.	1	3	29	1891	B, 7 inches	1,180	1,137	63	.....	...do..	Hand.....	100	.....	.....	Dom.
87	M. D. Easton.....	1	3	29	1890	B, 7 inches	1,121	1,101	45	.....	Soft..	Wind.....	80	70	0.008	Dom.
88	Barton Land and Water Co.	1	3	29	1891	B, 7 inches	1,130	1,100	48	.....	Hard.	Hand.....	.....	.....	.....	Dom.
89	J. R. Campbell.....	1	3	29	1893	B, 7 inches	1,190	1,155	103	.....	...do..	.....do.....	190	25	.....	Dom.
90	Carl Furst.....	1	3	29	1891	B, 5½ inches	1,215	1,180	114	.....	...do..	.....do.....	165	35	.....	Dom.
91	S. E. Rockwell.....	1	3	29	1900	B, 10 inches	1,200	1,170	356	SGR.....	Soft..	Cylinder pump; gas.	1,000	860	0.34	Irr.
92	J. Hickey.....	1	3	29	1898	B, 9½ inches	1,226	1,190	152	GC.....	...do..	.....do.....	314	700	0.20	Irr; dom.
93	B. M. James.....	1	3	29	1899	B, 10 inches	1,230	1,198	220	LSGC.....	...do..	.....do.....	418	900	0.34	Irr; dom.
94	W. A. Nichols.....	1	3	28	1891	B, 7 inches	1,246	1,194	122	.....	.....	Hand.....	.....	.....	.....	Dom.
95	.....do.....	1	3	28	.....	B, 10 inches	1,255	1,202	284	GCSR.....	.....	Cylinder pump; gas.	580	1,000	0.38	Irr.
96	W. D. Tobey.....	1	3	29	.....	B, 10 inches	1,204	.....	324	.....	.....	.....do.....	.....	.....	.....	Irr.
97	S. A. Grover.....	1	3	28	1899	B, 10 inches	1,253	1,183	231	SC.....	Hard..	.....do.....	700	1,100	0.40	Dom; irr.
98	Schee Bros.....	1	3	28	1899	B, 10 inches	1,280	1,210	425	Gravel.....	Soft..	.....do.....	1,400	1,500	0.50	Dom; irr.
99	W. F. Schee.....	1	3	28	1894	B, 7 inches	1,291	.....	.....	.....	...do..	.....do.....	.....	.....	.....	Irr.
100	Redlands Water Co..	1	3	35	1899	B, 10 inches	1,565	.....	.....	.....	Hard..	Centrifugal; steam..	.....	.....	1.56	Irr.
101	Barton Land and Water Co.	1	3	28	1900	B, 10 inches	1,315	1,225	250	.....	.....	.....	.....	.....	.....	.....
102	Willis Miller.....	1	3	21	1893	B, 7 inches	1,290	1,203	123	SG.....	Hard..	Wind.....	200	125	0.002	Dom.
103	S. A. Grover.....	1	3	21	1890	B, 7 inches	1,294	.....	.....	.....	...do..	.....do.....	.....	.....	.....	Dom; irr.
104	C. Cutting.....	1	3	21	1894	B, 7 inches	1,320	1,220	170	.....	Soft..	Cylinder pump; gas.	337	340	.....	Dom; irr.
105	Myron Sherman.....	1	3	27	1892	B, 8 inches	1,331	1,221	145	.....	...do..	Cylinder pump; electric.	450	300	.....	Dom; irr.
106	J. S. Hale.....	1	3	21	1897	B, 11 inches	1,272	1,202	205	Gravel.....	Hard..	Cylinder pump; gas.	600	1,300	0.48	Irr.
107	.....do.....	1	3	21	1890	B, 7 inches	1,265	1,201	105	.....	...do..	Wind.....	159	200	0.002	Dom; irr.
108	.....do.....	1	3	17	1896	B, 10 inches	1,220	1,164	86	.....	...do..	.....do.....	160	75	0.015	Irr.
109	C. A. Shaw.....	1	3	21	1893	B, 7 inches	1,267	1,217	96	.....	Soft..	.....do.....	138	87	0.005	Dom; irr.
110	Lewis Deck.....	1	3	21	1895	B, 7 inches	1,278	1,213	220	GC.....	...do..	Cylinder pump; gas.	363	678	0.15	Dom; irr.
110a	.....do.....	1	3	21	1895	B, 7 inches	1,278	1,213	150	GC.....	...do..				0.15	Dom; irr.
111	I. E. Shaw.....	1	3	21	1890	B, 7 inches	1,247	1,197	90	.....	...do..	Hand.....	150	25	.....	Dom.
112	Alise Van A. Lea.....	1	3	21	1898	B (2)	1,253	.....	70 130	SLC.....	Hard..	Cylinder pump; gas.	500	700	.....	Not used.
113	A. Gregory.....	1	3	21	1890	B, 7 inches	1,245	1,194	100	.....	Soft..	Wind.....	.....	.....	.....	Dom.

Wells in Redlands quadrangle—Continued.

No. of well.	Owner.	Location (T. R. S.)			Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S.	W.				Feet.	Feet.	Feet.						Sec.-ft.	
114	Gladysta Land and Water Co.	1	3	20	1899	B, 11 inches	1,240					Cylinder pump; gas.				Irr.
115	Frank Hess	1	3	21	1897	B, 11 inches	1,243	1,188	163		Soft	Centrifugal; gas.	$326	$800	0.24	Dom; irr.
116	C. S. Lombard	1	3	16	1897	B, 10 inches	1,246	1,182	180		Hard	Cylinder pump; gas.			0.30	Dom; irr.
117	S. Ronzone	1	3	16	1899	B, 9 inches	1,257	1,192	98	LSG	do	Wind	235	200	0.014	Dom; irr.
118	Thos. Blakeley	1	3	16		B	1,254				do	Electric				Irr.
119	Elza Boger	1	3	16	1899	D, 4 by 4 feet; B, 9 inches	1,255	1,185	132	(*)						
120	M. R. Gay	1	3	17	1896	B, 11 inches (2)	1,220	1,170	105	SGC	Hard	Air compressor; electric.	200		0.22	Irr.
121	W. W. Story	1	3	16	1900	B, 10 inches	1,262	1,193	163	GC	do	Cylinder pump; gas.	400	1,500	0.50	Dom; irr.
122	John Dostal	1	3	15	1897	B, 10 inches	1,403	1,230	174	HpSG	Soft	Wind	348	140	Small.	Dom.
123	J. F. Boyd	1	3	16	1896	B, 10 inches (2)	1,290	1,180	100; 110		do	Cylinder pump; gas.	500	900	0.20	Irr; dom.
124	Wm. Lindenberg	1	3	20	1893	B, 7 inches	1,220	1,180	93		Hard	Wind	140	150	0.009	Irr; dom.
125	H. S. Drew	1	3	19		B, 14 inches; B, 10 inches	1,167	1,133	164; 291		Soft	Cylinder pump; gas.	1,300	1,500	0.60	Irr; dom.
126	James Smith	1	3	19	1892	B, 7 inches	1,164	1,130	90		Hard	Hand	150	10		Dom.
127	Bryan estate	1	3	20	1900	B, 10 inches; B, 8 inches	1,190	1,143	510; 118		do	Centrifugal; gas.			0.40	Irr.
128	A. M. Ham	1	3	30	1887	B, 7 inches; B, 5 inches	1,155	1,120	150; 300			Cylinder pump; gas.	1,500	900		Dom; irr.
129	P. H. Covington	2	3	10		B, 7 inches	1,440	1,392	58		Hard	Hand				Dom.
130	Clark & Brotherton	1	3	20	1900	B, 10 inches; B, 8½ inches	1,195	1,162		LCG*						
131	J. J. Prendergast	1	3	29	1893	B, 10 inches	1,200	1,166	422		Hard	Cylinder pump; gas.	1,200	800	0.30	Irr; dom.
132	H. H. Cole	1	3	30	1888	B, 7 inches	1,140	1,108	82	LSG		Wind	140	180	Small.	Irr; dom.
133	H. S. Drew	1	3	19	1886	B, 7 inches	1,138		70		Hard	do	140	150	0.001	Dom.
134	C. M. Baxter	1	3	30	1899	B, 10 inches	1,147	1,116	100			Centrifugal; gas.			0.60	Irr.
135	do	1	3	30	1892	B, 7 inches	1,147	1,113	80		Hard	Hand				Dom.
136	C. H. Lehmann	1	3	19	1891	B, 10 inches	1,129	1,103	458		Soft	Cylinder pump; gas.	1,300	900	0.40	Irr; dom.
137	A. E. Cole	1	3	30	1892	B, 7 inches	1,125	1,104	100	LSGC	Hard	Wind	160	100	0.005	Irr; dom.
138	A. McCrary	1	3	30	1891	B, 7 inches	1,120	1,093	40	CG	do	Hand	64			Dom.
139	H. R. Scott	1	3	19		B, 7 inches	1,120	1,108	503		do	Centrifugal; gas.	1,000	1,000		Irr; dom.
140	do	1	3	19	1879	B, 6 inches	1,127	1,109	500		do					
141	E. H. Durnford	1	4	24	1894	B, 7 inches	1,103	1,093	500		Soft	Centrifugal; gas.			0.60	Dom; irr.
142	James Birch	1	4	24	1890	B, 7 inches	1,096	1,087	300		do					Dom.
143	do	1	4	24		B, 7 inches	1,098	1,081	100							
144	D. W. Roach	1	4	24	1899	B, 7 inches	1,102	1,087	85	SG	Hard	Hand	130	24		Dom.
145	E. F. Van Leuven	1	4	25	1890	B, 7 inches	1,103	1,083	48		do	Wind			0.001	Dom.

146	W. H. Van Leuven	1	4	25	.....	B, 7 inches	1,101	1,081	75	.....	...do	...do	.....	.....	.....	Dom; irr.
147	W. J. Doran	1	3	30	1900	B, 10 inches	1,106	1,086	100	.....	...do	...do	200	.....	.....	Dom.
148	L. R. Van Leuven	1	3	30	1882	B, 7 inches	1,108	1,093	270	.....	...do	...do	600	109	0.001	Dom; irr.
149	.....	1	3	30	.....	B, 7 inches	1,120	.....	.....	.....	...do	...do	.....	.....	.....	Dom; irr.
150	O. Taylor	1	3	32	1897	B, 7 inches	1,210	.....	75	.....	...do	...do	.....	120	0.008	Dom; irr.
151	H. C. Hamanway	1	3	32	.....	B, 7 inches	1,209	.....	.....	.....	...do	Hand	.....	.....	.....	
152	G. J. Grant	1	3	32	1896	B, 7 inches (2)	1,206	.....	.....	.....	...do	Gas	.....	.....	.....	Irr; dom.
153	S. L. Gregg	1	3	32	.....	B, 7 inches	1,202	.....	.....	.....	...do	Wind	.....	.....	.....	Dom.
154	H. C. Hamanway	1	3	32	1899	B, 10 inches	1,250	1,198	200	.....	...do	Cylinder pump; gas	.....	.....	0.32	Irr.
155	T. Morris	1	3	32	1890	B, 7 inches	1,260	1,195	125	LCG	...do	Wind	.....	.....	0.002	Irr; dom.
156	S. V. Horton	1	3	32	1891	B, 7 inches	1,270	1,195	125	LCG	.....	...do	200	175	0.01	Irr; dom.
157	C. T. Covington	2	3	4	1891	B, 7 inches	1,455	1,415	65	SG	Hard	Hand	100	25	.....	Dom.
158	Mrs. Van Leuven	1	4	25	1896	B, 7 inches	1,105	1,085	78	.....	...do	...do	150	15	.....	Dom.
159	J. H. Pierson	1	4	24	1884	B, 6 inches	1,104	1,103	605	CG	...do	Centrifugal; gas	10,222	1,200	0.60	Dom; irr.
160	F. M. Strang	2	3	10	1897	D, 3 by 3 feet	1,500	1,423	79	SG	...do	Hand	77	4	.....	Dom.
161	Railroad School	2	3	10	1891	B, 7 inches	1,527	,427	118	CG	...do	...do	180	25	.....	Dom.
162	D. Mulvahill	2	3	10	1891	B, 7 inches	1,470	,439	61	CG	...do	...do	115	22	.....	Dom.
163	R. P. Lauretzen	2	3	10	.....	B, 7 inches	1,550	,474	106	.....	...do	...do	.....	.....	.....	Dom.
164	.....	2	3	4	.....	B, 7 inches	1,430	.....	.....	.....	...do	...do	.....	.....	.....	Dom.
165	— DeGarmo	2	3	8	.....	B, 7 inches	1,575	1,485	164	.....	...do	Wind	.....	.....	.....	Dom.
166	Smiley Bros	2	3	4	.....	D, 7 by 7 feet	1,347	1,330	23	.....	...do	Centrifugal; gas	.....	.....	0.50	Irr.
277	L. F. Cram	1	3	3	1895	B, 12 inches	1,305	1,189	116	SCGR	Soft	Wind	1,000	100	Small.	Dom; irr.
278	C. C. Tyler	1	3	2	1900	D, 4 by 5 feet	1,305	.....	.....	SCGR	.....	.....	.....	.....	.....	
279	John McBride	1	2	6	1900	D, 4 by 4 feet	1,650	1,636	65	SGB	.....	Centrifugal; gas	500	400	.....	Irr; dom.
280	.....do	1	2	6	1894	H, 4 by 6 feet	1,654	1,654	130	Granite	Hard	Tunnel, 180 ft., flows.	250	.....	0.02	Irr.
281	Cram Bros	1	3	2	1899	D, 4 by 4 feet	1,600	1,485	120	CG	.....	.....	300	.....	.....	
282	E. Highland Orange Co.	N. W. 1	3	35	1900	B, 12 inches B, 10 inches	1,630	1,610	280 140	SGR	.....	Tunnel, flows	1,680	.....	0.26	Dom; irr.
283	.....do	1	3	35	1900	D, 4 by 4 feet B, 10 inches	1,680	1,666	.....	SGR	.....	.....	.....	.....	.....	
284	W. M. Bristol	1	3	34	1899	D, 5 by 5 feet	1,650	1,634	50	Gravel	Soft	Cylinder pump; gas	.....	1,250	0.30	Irr.
285	Highland Domestic Water Co.	1	3	27	1899	D, 7 by 9 feet	1,440	1,411	65	GB	.....	2 cylinder pumps; 2 gas engines.	.....	[b]1,500	1.10	Dom.
286	Highland Well Co	S. W. 1	3	28	1899	D, 8 by 5 feet	1,431	1,415	46	.....	.....	Cylinder pump; gas	.....	.....	0.68	Irr.
287	J. C. Weeks	1	3	3	1900	D, 4 by 4 feet B, 12 inches	1,295	1,181	(a)	.....	Hard	.....	.....	.....	.....	
288	H. S. Stroven	1	3	3	1898	B, 10 inches	1,253	1,173	165	.....	Soft	Cylinder pump; gas	400	1,160	0.40	Irr; dom.
289	N. Sutherland	1	3	4	1898	Dug B, 12 inches	1,227	1,160	78	.....	Hard	.....	.....	.....	.....	Not used.
290	Pattee & Nye	1	3	5	1900	D, 6 by 8 feet B, 10 inches	1,200	1,150	50 100	.....	.....	Rotary pump; steam	.....	.....	0.60	Irr.
291	G. J. Fowler	1	3	5	1899	D, 5 feet	1,180	1,127	55	SCG	Soft	Hand	50	17	.....	Dom.
292	R. F. Cunningham	1	3	5	1890	D, 6 feet	1,160	1,120	43	Gravel	...do	Centrifugal; steam	150	1,450	0.80	Irr.
293	.....do	1	3	5	1899	B, 7 inches	1,147	1,108	36	.....	...do	Hand	160	15	.....	Dom.
294	.....do	N. W. 1	3	31	1900	D, 5 by 5 feet B, 10 inches	1,260	1,226	135 90	CG	.....	Steam	.....	.....	1.04	Irr.

[a] Unfinished.

[b] Two engines.

Wells in Redlands quadrangle—Continued.

No. of well.	Owner.	Location (T.R.S.).	Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S. W.			Feet.	Feet.	Feet.						Sec.-ft.	
295	Redlands Water Co.	1 3 35	1899	B, 10 inches	1,568				Hard					
296	C. K. Matteson	1 3 7	1892	B, 10 inches	1,107	1,083	47	CG	Soft	Centrifugal; steam	$500		0.20	Irr.
297	do	1 3 7	1884	Dug	1,103	1,080	25	SGC	do	Hand	30	$4		Dom.
298	do	1 3 7	1894	B, 10 inches	1,103	1,083	44	SG	do	Centrifugal; gas	175	510	0.60	Irr.
299	Geo. Gustave	1 3 7	1900	D, 4 by 6 feet	1,101	1,082	25	SGR	do	do	50		0.30	Irr; dom.
300	do	1 3 7		D, 3 by 4 feet	1,103	1,085	19	SGB	do					
301	Mrs. H. Taylor	1 3 7		D, 3 feet	1,102	1,080	25	Gravel		Centrifugal; steam				Irr.
302	C. Wiltshire	1 3 6	1895	Dr, 2 inches	1,102	1,080	27		Soft	Hand		25		Dom.
303	Mrs. H. Taylor	1 3 7	1891	B, 3 inches	1,101		235		do	do	300		3.00	Dom; irr.
304	W. F. Somers	1 3 7	1900	B, 10 inches	1,101	1,081	(a)	SGCB						
305	Mrs. Golden	1 4 12	1900	B, 10 inches	1,099	1,099		SGC		Artesian				Irr.
306	do	1 4 12	1898	B, 8 inches	1,102	1,102	744		Soft	do	1,600		b1.10	Dom; irr.
307	W. F. Somers	1 3 7	1895	Dug	1,098	1,080	20		do	Hand	20		7.00	Dom.
308	do	1 3 7	1899	D, 3 by 3 feet	1,097	1,079	20		do	do	20		4.00	St.
309	John Kaus	1 3 7	1899	B, 8 inches	1,103	1,085	20			Steam	40			Dom.
310	F. P. Sargent	1 4 13	1894	Dr, 2 inches	1,096	1,084	24	Sand	Hard	Hand	15	10		Dom.
311	S. E. Fitzhugh	1 4 12	1888	B, 3 inches	1,080	1,073	234	SGC	Soft	do	500	6		Dom.
312	do	1 4 12	1885	B, 7 inches	1,081	1,064	20		Hard	do	35	6		Dom.
313	W. Borne	1 3 7		D, 3½ by 3½ feet	1,103					do				Dom.
314	Geo. Covalt	1 3 7	1899	B, 7 inches	1,104	1,079	30		Hard	do		4		Dom.
315	W. F. Somers	1 4 1		B, 3 inches	1,099	1,095	283		Soft	do				Dom.
316	W. K. Bledsoe	1 4 1		D, 4½ feet	1,103	1,086	21	SG	Hard	do	25	3		Dom.
317	T. J. West	1 4 1	1900	D, 5 feet	1,093	1,090	20	SG	Soft	Centrifugal; steam	400	820	1.30	Irr.
318	S. Van Leuven	1 3 6	1883	B, 3 inches	1,104	1,105	309		do	Wind				Irr; dom.
319	Ed. Dailey	1 3 6	1890	B, 3 inches	1,102	1,091	325		do	Hand				Dom.
320	do	1 3 6	1890	B, 3 inches	1,106	1,105	320		do					Not used.
321	do	1 3 6	1885	B, 3 inches	1,103	1,093	350		do	Hand				Dom.
322	W. A. Brouse	1 3 6	1899	Dug	1,104	1,084	22	SG	do	do	25	5		Dom.
323	do	1 3 6	1884	D, 5 feet	1,104	1,084	26	SG	do	Centrifugal; steam	150	630	0.50	Irr.
324	do	1 3 6	1893	D, 5 feet	1,106	1,086	25		do	do	150	630	0.50	Irr.
325	Herman Smith	1 3 6	1899	D, 4 by 4 feet	1,109	1,084	27	SG	do	Hand	100	12		Dom.
326	J. Friedmann	1 3 6	1885	D, 6 feet	1,107	1,090	22	SG	do	Centrifugal; steam	130	485	1.00	Irr; dom.
327	J. Dunlap	1 4 1		B, 3 inches	1,102	1,102	185		Hard	Artesian			0.18	Dom.
328	H. C. Keller	1 4 1	1880	B, 2 inches	1,104	1,104	169		Soft	do			0.02	Dom.
329	A. Roberts	1 3 6	1892	B, 3 inches	1,105	1,105	231		do	do	426		0.005	Dom.
330	Warm Creek School	1 3 6	1885	B, 2 inches	1,106	1,101	150			Hand	175			Dom.
331	W. L. McKenzie	1 4 1	1875	B, 2 inches	1,105	1,105	320		Soft	Artesian			0.01	Irr; dom
		N. W.												
332	Wm. Shay	1 3 31	1890	B, 3 inches	1,103	1,103	150		do	do	300		0.06	Dom.

		S.	W.													
333	Wm. Clyde	1	3	6	1869	B, 2 inches	1,106	1,106	146		Soft	Artesian	150		0.03	Irr; dom.
334	Riverside Water Co.	1	4	1	1898	B, 10 inches	1,086		648	CGS	Hard	do				Irr.
335	do	1	4	1	1898	B, 10 inches	1,088		590	SGC	do	do	1,100		1.20	Irr.
336	do	1	4	1	1898	Bored	1,085		384	SCG	do	do				Irr.
337	do	1	4	1		Bored	1,084	1,084	440		do	do				Irr.
338	Redlands Dom. W. Co	1	3	35	1899	B, 10 inches (2)	1,640	1,550	243 400	CSG	do	Centrifugal; electric	650		0.80	Dom.
		N.	W.													
339	Thomas Shay	1	3	31	1888	B, 7 inches	1,108	1,089	20	SGC	Soft	Hand	30	5		Dom.
340	do	1	3	31	1895	D, 4 by 4 feet B, 8 inches	1,098		80		Hard	Cylinder pump; gas.	300	1,680	0.50	Irr.
		S.	W.													
341	R. T. Clyde	1	3	6	1880	B, 2 inches	1,105	1,105	133		Soft	Artesian	100			Dom; irr.
342	F. L. Talmadge	1	3	6	1880	B, 2 inches	1,106	1,106	135		do	Hand	100	5		Dom.
343	Talmadge & Haws	1	3	6	897	B, 10 inches	1,140	1,132	425	SCBG	do	Centrifugal; gas.	850	988	2.00	Irr.
344	Mrs. Haws	1	3	6	1898	B, 2 inches	1,125	1,125	100		do	Hand	75	8		Dom.
		N.	W.													
345	John D. Clark	1	3	31	1890	B, 3 inches	1,130	1,130	125	LCSG	Hard	Artesian	120		0.02	Dom; irr.
346	do	1	3	31	1892	B, 3 inches	1,132	1,132	50	CG	do	do	45			Dom; irr.
347	D. R. Seely	1	3	33	1890	B, 3 inches	1,250	1,176	124		Soft	Wind			0.005	Dom.
348	do	1	3	33	1899	B, 12 inches	1,285	1,110	195			Cylinder pump; gas.				Irr.
		S.	W.													
349	W. D. Stevens	1	3	5	1894	D, 8 feet B, 10 inches	1,180	1,130	40 60		Hard	Centrifugal; gas.		815	0.60	Irr; dom.
350	Jane C. Goodman	1	3	6	1894	B, 3 inches	1,140	128	284		do	Wind	625	108	0.001	Irr; dom.
351	Jas. Roddick	1	3	5	1898	D, 4 inches	1,143	114	30		do	Centrifugal; gas.		250	0.20	Irr; dom.
352	Saml. Roddick	1	3	6	1899	Dr, 1¼ inches	1,139	117	27		do	Hand	7	10		Dom.
353	W. F. Talmadge	1	3	6	1885	B, 7 inches	1,148	132	30		do	Wind		80	0.001	Dom; irr.
354	do	1	3	6	1891	B, 3 inches	1,146	1,131	41		do	Hand		6		Dom.
355	A. Downey	1	3	6	1899	Dr, 1¼ inches	1,143	1,131	21		Soft	do	4	3		Dom.
356	F. A. Haws	1	3	6	1899	Dr, 1¼ inches	1,130	1,120	26		Hard	do	5	5		Dom.
357	E. S. Haws	1	3	6	1899	Dr, 1¼ inches	1,130	1,120	20		do	do	5	5		Dom.
358	Mrs. M. C. Haws	1	3	6	1895	B, 3 inches	1,125	125	125		Soft	Artesian	250			Dom.
		N.	W.													
359	Walter Shay	1	3	31		B, 7 inches	1,110				Hard	Hand				Dom.
360	Kohl Bros.	1	3	32	1890	B, 6 inches	1,147	1,129	60		do	Wind			0.001	Dom.
361	H. D. Rabel	1	3	31	1896	B, 2 inches	1,140	1,140	68		Soft	Artesian	40			Dom.
362	do	1	3	31	1898	B, 3 inches	142	1,142	86		do	do	70		0.01	Dom.
363	do	1	3	31	1898	B, 3 inches	1,139	1,139	44		do	do	30		0.25	Dom.
364	do	1	3	31		B, 3 inches	1,137	1,137	72		do	do	70		0.005	Dom.
365	Geo. Miller	1	3	32	1898	B, 6½ inches	1,130	1,043	92		do	Wind	700	100		Dom.
366	D. J. Carpenter	1	4	24	1900	D, 6 by 9 feet	1,470	1,447	25	CS	Alk					
367	D. J. Carpenter & Co.	1	4	24		B, 7 inches	1,475	1,475	71	SG	do				0.06	Irr.
368	do	1	4	24		B, 7 inches	1,474	1,474	123	SG	do				0.10	Irr.
369	do	1	4	24		B, 7 inches	1,474	1,474	193	SG	do				0.08	Irr.
370	do	1	4	24		B, 7 inches	1,476	1,476	184	SG	do	Centrifugal; gas.		1,100	0.14	Irr.
371	do	1	4	24		B, 7 inches	1,473	1,473		SG	do				0.10	Irr.
372	do	1	4	24		B, 7 inches	1,473	1,473	127	SG	do				0.10	Irr.
373	do	1	4	24		B, 7 inches	1,473	1,473	167	SG	do				0.06	Irr.
374	W. J. Linville	1	3	30	1899	B, 10 inches	1,270	1,140	368		Hard	Cylinder pump; gas.		3,000	0.36	Irr.

[a] Not completed.

[b] December, 1898.

Wells in Redlands quadrangle—Continued.

No. of well.	Owner.	Location (T. R. S.).	Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S. W.			*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
375	Mrs. R. L. Burcham	1 3 31	1899	B, 12 inches	1,224	1,154	460		Soft	Cylinder pump; gas.	$1,200	$2,250	0.70	Irr.
376	E. K. Henderson	1 3 30	1899	B, 3 inches	1,233	1,133	134		do	Wind	150			Dom.
377	Jas. McCafferty	1 3 31	1896	B, 7 inches	1,225		80–100		do	Cylinder pump; gas.		2,500	0.40	Irr; dom.
378	J. D. Clark	1 3 31	1897	B, 11 inches	1,170		106	LCB	do	do			0.40	Irr.
379	P. W. Gray	1 3 31	1893	B, 7 inches	1,170	1,120	139		Hard	Wind			0.03	Dom; irr.
380		1 3 30	1900	B, 7 inches	1,310		320	SCGB						
381	John Lin Foster	1 3 32	1894	B, 10 inches	1,220		95		Soft	Wind	600	(a)	0.006	Dom; irr.
382	P. H. Gleason	1 3 32	1900	D, 4 by 4 feet	1,250	1,175	78		do	do			0.002	Dom; irr.
383	E. L. Cumbl	1 3 32	1897	D, 4 by 4 feet	1,128	1,091	38	CSB	Hard	Hand	50			Dom.
384	A. C. Pierce	1 3 32	1898	D, 4 by 4 feet	1,210	1,150	62	LSGB	Soft	Wind	120	140	0.005	Dom; irr.
385	Kohl Bros	1 3 32	1898	B, 10 inches	1,148	1,136	300	SGB	do	Centrifugal; gas.	600	700	1.60	Dom; irr.
		S. W.												
386	State of California Hospital for Insane.	1 3 5		B, 10 inches	1,110	1,078	85		Hard	Centrifugal; steam.			1.60	Irr.
		N. W.												
387	Geo. Fowler	1 3 32	1888	D, 3 by 3 feet	1,165	1,137	29	CG	Soft	Hand				Dom.
		S. W.												
388	C. D. Fowler	1 3 5	1895	D, 4 feet	1,168	1,135	34	CSGB	Hard	do				Dom.
		N. W.												
389	J. Bagwell	1 3 32	1900	D, 4 by 4 feet; B, 12 inches	1,230	1,117	153		do	Cylinder pump; gas.			0.20	Irr.
390	A. A. Boyd	1 3 32	1895	Dug; B, 7 inches	1,290	1,138	202		do	do			0.22	Irr; dom.
391	Gage Canal Co.	1 4 13	1891	B, 10 inches	1,058	1,058	168		do	Artesian			b 4.306	Irr.
392	do	1 4 13	1891	B, 10 inches	1,059	1,059	166		do	do			b 1.521	Irr.
393	do	1 4 13	1891	B, 10 inches	1,061	1,061	152		do	do			b 1.521	Irr.
394	do	1 4 13	1891	B, 10 inches	1,063	1,063	123		do	do			b 1.712	Irr.
395	do	1 4 13	1891	B, 10 inches	1,066	1,066	125		do	do			b 0.594	Irr.
396	do	1 3 18	1887	B, 10 inches	1,062	1,062	144		do	do			b 2.181	Irr.
397	do	1 3 18	1887	B, 10½ inches	1,064	1,064	140		do	do			b 1.011	Irr.
398	do	1 3 18	1888	B, 10 inches	1,075	1,075	138		do	do			b 0.606	Irr.
399	do	1 3 18	1888	B, 10 inches	1,075	1,075	106		do	do			b 0.188	Irr.
400	do	1 3 18	1888	B, 10 inches	1,074	1,074	130		do	do			b 0.563	Irr.
401	do	1 3 18	1888	B, 10 inches	1,071	1,071	146		do	do			b 2.212	Irr.
402	do	1 3 18	1888	B, 10 inches	1,065	1,065	116		do	do			b 3.176	Irr.
403	do	1 3 18	1888	B, 10 inches	1,064	1,064	134		do	do			b 1.424	Irr.
404	do	1 3 18	1888	B, 10 inches	1,061	1,061	116		do	do			b 0.594	Irr.
405	do	1 4 13	1887	B, 10 inches	1,057	1,057	147		do	do			b 2.254	Irr.
406	do	1 4 13	1887	B, 10 inches	1,058	1,058	122		do	do			b 1.026	Irr.
407	do	1 4 13	1892	B, 10 inches	1,059	1,059	115		do	do			b 0.484	Irr.

408	do	1	4	18	1892	B, 10½ inches	1,053	1,053	169		do	do			[a] 8.105	Irr.
409	do	1	3	18	1886	B, 7 inches	1,077		127		do	[d]			[c] 0.286	Irr.
410	do	1	3	18	1886	B, 7 inches	1,076		127		do	[d]			[c] 0.302	Irr.
411	do	1	3	18	1886	B, 7 inches	1,077		125		do	[d]			[c] 0.270	Irr.
412	do	1	3	18	1886	B, 7 inches	1,077		125		do	[d]			[c] 0.416	Irr.

[a] Included in cost of well.
[b] Flow of wells Nos. 391 to 412 is given for October, 1892.
[c] December, 1898.
[d] Wells 409 to 412 are pumped by 15-horsepower gas engine and centrifugal pump, raising 2 second-feet of water. These were artesian wells when sunk.

Wells in San Bernardino quadrangle.

No. of well	Owner of well.	Location (T.R.S.).			Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S.	W.				Feet.	Feet.	Feet.						Sec.-ft.	
1	Riverside Water Co.	1	4	27	1887	11-inch pipe	1,014	1,014	115		Hard	Artesian			[a] 0.329	Dom.
2	do	1	4	27		11-inch pipe	1,015	1,015	118		do	do			[b] 0.284	Dom.
3	do	1	4	27		11-inch pipe	1,015	1,015	113		do	do			[b] 0.117	Dom.
4	do	1	4	27		11-inch pipe	1,016	1,016	111		do	do			[b] 0.153	Dom.
5	do	1	4	27		11-inch pipe	1,014	1,014	112		do	do			[b] 0.117	Dom.
6	do	1	4	27		11-inch pipe	1,016	1,016	120		do	do			[b] 0.150	Dom.
7	do	1	4	27	1888	7-inch pipe	1,013	1,013	128	BCS	do	do	$400		[b] 0.150	Dom.
8	do	1	4	27	1888	9-inch pipe	1,016	1,016	125	BCS	do	do	525		[b] 0.096	Dom.
9	do	1	4	27	1888	9.5-inch pipe	1,018	1,018	123	BCS	do	do	500			Dom.
10	do	1	4	27	1888	9-inch pipe	1,017	1,017	127	BCS	do	do	550			Dom.
11	do	1	4	27	1888	9-inch pipe	1,021	1,021	201	BCS	do	do	800		[b] 0.125	Dom.
12	do	1	4	27		9-inch pipe	1,020	1,020	141	BCSG	do	do	650			Dom.
13	do	1	4	27	1889	9-inch pipe	1,015	1,015	127	CSGB	do	do	525			Dom.
14	do	1	4	27	1889	9-inch pipe	1,014	1,014	125	CSGB	do	do	550		[b] 0.098	Dom.
15	do	1	4	22	1889	11-inch pipe	964	964	86	CSGB	do	do	480		[c] 0.442	Irr.
16	do	1	4	22	1889	9-inch pipe	981	981	123	CSBG	do	do			[c] 0.083	Irr.
17	do	1	4	22	1889	9-inch pipe	955	955	81	SCB	do	do			[c] 0.900	Irr.
18	do	1	4	22	1889	9-inch pipe	955	955	92	SGCB	do	do			[c] 0.361	Irr.
19	do	1	4	16	1889	9-inch pipe	972	972	225	SCGB	do	do			[b] 0.158	Irr.
20	do	1	4	16	1889	7-inch pipe	978	978	75	CSB	[d]	[d]			[d]	
21	do	1	4	16	1891	7-inch pipe	971	971	175	SCB	[d]	[d]			[d]	
22	do	1	4	16	1889	9-inch pipe	973	973	55	CSB	Hard	Artesian			0.173	Irr.
23	do	1	4	16	1889	9-inch pipe	974	974	121	SBCS	do	do			0.355	Irr.
24	do	1	4	22	1889	7-inch pipe	989	989	192	CSGB	do	do			[c] 0.175	Irr.
25	do	1	4	22	1889	9-inch pipe	968	968	81	SCGB	do	do			[c] 0.207	Irr.
26	do	1	4	22	1889	9-inch pipe	967	967	83	SCB	do	do			[c] 0.361	Irr.
27	do	1	4	22	1889	9-inch pipe	981	981	103	SCGB	do	do			[c] 0.952	Irr.

[a] 1890. [b] 1891. [c] 1896. [d] Well filled and covered with sand from flood and lost.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner of well.	Location (T. R. S.).			Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S.	W.				*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
28	Riverside Water Co.	1	4	22	1889	9-inch pipe	970	970	83	SCB	Hard.	Artesian			[a]0.278	Irr.
29	....do	1	4	22	1889	9-inch pipe	979	979	101	SCGB	....do	....do			[a]0.640	Irr.
30	....do	1	4	22	1890	9-inch pipe	978	978	97	SCGB	....do	....do			[a]1.417	Irr.
31	....do	1	4	22	1890	9-inch pipe	980	980	165	SCGB	....do	....do			[a]0.569	Irr.
32	....do	1	4	22	1890	9-inch pipe	979	979	165	SCBG	....do	....do			[a]0.616	Irr.
33	....do	1	4	27	1891	9.5-inch pipe	1,012	1,012	330	SGCR	....do	....do			[b]8.28	Dom.
34	....do	1	4	27	1891	9.5-inch pipe	1,012	1,012	326	CSGR	....do	....do				Dom.
35	....do	1	4	27	.....	9.5-inch pipe	977	977	82	CSGB	....do	....do	$255		[c]0.860	Irr.
37	....do	1	4	25	.....	9.5-inch pipe	1,012	1,012	249	CSGR	....do	....do				Dom.
38	....do	1	4	1	1892	7-inch pipe	1,083	1,083	187	SGC	....do	....do	662		[d]0.027	Irr.
39	....do	1	4	1	1893	9.5-inch pipe	1,083	1,083	396	SBCRG	....do	....do			[d]0.714	Irr.
42	....do	1	4	25	1893	9.5-inch pipe	1,011	1,011	344	CSB	....do	....do				Dom.
43	....do	1	4	1	1894	9.5-inch pipe	1,086	1,086	420	SGC	....do	....do	630		[c]1.452	Irr.
44	....do	1	4	22	1896	9-inch pipe	979	979	133	.....	....do	....do	250		[a]0.971	Irr.
45	....do	1	4	22	1896	9-inch pipe	979	979	173	SB	....do	....do	420			Irr.
47	....do	1	4	3	1898	9-inch pipe	1,025	1,025	168	SB	....do	....do	500			Irr.
51	....do	1	4	22	.....	8-inch pipe	954	954	78	.....	....do	....do	.....	.....	.....	Irr.
52	....do	1	4	22	.....	8-inch pipe	955	955	94	SCG	....do	....do	.....	.....	.....	Irr.
53	....do	1	4	22	1898	8-inch pipe	956	956	68	SCG	....do	....do	.....	.....	.....	Irr.
54	....do	1	4	22	1898	8-inch pipe	957	957	68	.....	....do	....do	.....	.....	.....	Irr.
55	....do	1	4	22	1898	7-inch pipe	958	958	92	.....	....do	....do	.....	.....	.....	Irr.
56	....do	1	4	22	1898	7-inch pipe	959	959	75	.....	....do	....do	.....	.....	.....	Irr.
57	....do	1	4	22	1898	8-inch pipe	960	960	92	CS	....do	....do	128	.....	.....	Irr.
58	....do	1	4	22	1898	7-inch pipe	960	960	87	CBGS	....do	....do	157	.....	[f]0.456	Irr.
59	....do	1	4	22	1898	8-inch pipe	961	961	85	SCB	....do	....do	138	.....	[f]0.622	Irr.
60	....do	1	4	22	1898	7-inch pipe	961	961	93	SCB	....do	....do	173	.....	[f]0.456	Irr.
61	....do	1	4	22	.....	8-inch pipe	952	952	.....	.....	....do	....do	.....	.....	.....	Irr.
62	....do	1	4	15	1898	8-inch pipe	985	985	183	SCG	....do	....do	.....	.....	[f]0.84	Irr.
65	....do	1	4	2	1900	10-inch pipe	1,040	1,040	540	GCS	Soft	....do	.....	.....	2.89	Irr.
66	....do	1	4	2	1900	10-inch pipe	1,035	1,035	580	GCSR	Hard.	....do	.....	.....	2.606	Irr.
67	Wm. Roach	2	4	6	1889	7-inch pipe	904	852	130	.....	Soft	10 wind	200	$160	0.015	Irr; dom.
68	....do	2	4	6	1875	7-inch pipe	905	852	70	.....	....do	12 wind	105	180	0.006	Irr.
69	Mrs. Douglas	2	4	6	1893	7-inch pipe	895	835	112	.....	....do	Wind	.....	.....	0.015	Irr; dom.
70	Louise Peña	2	5	12	1888	D, 3 by 4 feet	835	815	22	.....	Hard.	....do	.....	110	Small.	Dom.
71	P. Evans	2	5	12	1900	10-inch pipe	840	840	400	.....	.....	Artesian	.....	.....	1.000	Irr.
72	P. Baca	2	5	12	1899	D, 3 by 3 feet	852	832	22	.....	Hard.	Hand	20	.....	Small.	Dom.
73	W. L. Zader	1	4	29	1894	D, 3 feet dia	980	930	52	.....	....do	8 wind	40	95	....do	Dom.
74	D. Jones	1	4	29	1888	D, 3 feet dia	980	.....	70	.....	.....	Wind	100	200	.....	
75	T. J. Smith	1	4	30	1890	D, 3 feet dia	974	.....	38	.....	....do	....do	.....	.....	.....	
76	Mrs. B. R. Atkins	1	4	30	1897	D, 3 feet dia	980	938	59	.....	Hard.	9 wind	.....	500	Small.	Dom.

77	.....	1	4	30	.....	D, 3 by 3 feet	886	871	17	.....	.....	Hand	.....	.....	.....	Dom.
78	.....	1	4	30	.....	D, 3 by 3 feet	875	871	6	.....	.....	...do	.....	.....	.....	Dom.
79	Thos. McGraw	1	5	35	1895	D, 4 by 4 feet	875	837	39	SCG	Soft	...do	70	14	Small.	Dom.
80	Henry Carson	2	5	10	1900	D, 3 feet dia.	831	784	49	SGR	...do	.....	40	.....	.....	Dom.
81	Dan. Baker	2	5	10	1885	6-inch pipe	826	786	60	.....	...do	Hand	.....	20	.....	Dom.
82	Mrs. Burgess	1	5	34	.....	D, 4 by 4 feet	988	838	150	.....	.....	Wind	.....	.....	.....	Not used.
83	T. Pulley	2	5	10	(a)	B, 20 inches	881	808	89	.....	.....	.....	.....	.....	.....	.....
84	Mrs. L. M. Henry	2	5	10	1898	6-inch pipe	895	787	128	.....	Hard	Wind	.....	.....	.....	Irr; dom.
85	T. Pulley	2	5	10	1896	D, 3 feet dia	850	780	72	.....	...do	...do	50	120	.....	Irr; dom.
86	John Miller	2	5	10	1900	D, 3 feet dia	866	800	69	.....	Soft	...do	40	.....	.....	Dom.
87	Ed. Bridson	2	5	15	1898	7-inch pipe	840	780	100	GS	Hard	10 wind	150	150	.....	Dom; st.
88	J. Rogerson	2	5	15	.....	D, 4 by 4 feet	830	794	37	.....	.....	Hand	.....	.....	.....	Dom.
89	Mrs. A. Parks	2	5	15	.....	7-inch pipe	810	798	28	.....	Hard	Wind	.....	.....	.....	Dom; st.
90	H. C. Parks	2	5	9	1887	D, 3 feet dia	850	784	75	.....	...do	...do	325	180	.....	Dom; st.
91	Scott La Rue	2	5	9	1900	D, 3 feet dia	845	742	107	SG	.....	...do	100	285	.....	Dom; st.
92	Emuel Spooner	2	5	8	1896	D, 4 by 4 feet	850	750	105	SG	Hard	...do	115	.....	.....	Dom; st.
93	...do	2	5	8	1900	D, 4 by 4 feet	850	750	107	SG	.....	.....	125	.....	.....	.....
94	W. J. Thomas	2	5	7	1900	D, 4½ by 4 feet	847	817	35	SGB	Soft	.....	70	.....	.....	Dom.
95	E. Thomas	2	5	7	1899	D, 3 by 3 feet	850	814	41	SG	...do	Wind	75	150	.....	Irr.
96	...do	2	5	7	1894	D, 3 by 3 feet	841	817	26	.....	...do	Hand	40	.....	.....	Dom.
97	Mrs. H. M. Thurber	2	6	12	1896	D, 5 feet dia	800	782	28	.....	...do	Wind	.....	.....	.....	Irr; dom.
98	F. D. Lewis	2	6	13	.....	D, 4 by 4 feet	795	775	40	.....	...do	10 wind	.....	.....	.....	Dom.
99	.....	2	6	12	.....	D, 4 by 4 feet	789	770	31	.....	.....	...do	.....	.....	.....	Dom.
100	John Parkhurst	2	6	12	1898	D, 6 feet dia	818	807	13.5	SR	Soft	12 wind	100	135	.....	Dom.
101	J. R. Johnston	2	5	6	.....	Pipe line	.....	.....	.....	.....	.....	.....	.....	.....	.....	Dom.; st.
102	I. McBride	2	6	12	1892	D, 3.5 by 3.5 feet	813	787	55	SR	Soft	8 wind	80	100	Small.	Dom.
103	Milo Gilbert	1	4	24	1900	7-inch pipe	1,004	864	220	.....	.....	12 wind	.....	.....	.....	.....
104	Riverside Trust Co	1	4	24	1898	10-inch pipe	1,077	1,077	508	CSGR	Hard	Artesian	.....	.....	1.600	Irr.
105	...do	1	4	24	1898	10-inch pipe	1,071	1,071	531	CSG	...do	...do	.....	.....	1.200	Irr.
106	...do	1	4	24	1898	10-inch pipe	1,065	1,065	517	CSGR	...do	...do	.....	.....	1.400	Irr.
107	...do	1	4	23	1899	10-inch pipe	,045	1,045	675	CSGR	...do	...do	.....	.....	1.500	Irr.
108	...do	1	4	24	1899	10-inch pipe	1,076	1,076	568	CSGR	...do	...do	.....	.....	2.040	Irr.
109	...do	1	4	26	1899	10-inch pipe	1,019	1,019	554	CSGR	...do	...do	.....	.....	0.400	Irr.
110	...do	1	4	13	1899	10-inch pipe	1,052	1,052	580	.....	...do	...do	.....	.....	.....	Irr.
111	...do	1	4	13	1899	10-inch pipe	1,061	1,061	537	CSGR	...do	...do	.....	.....	2.600	Irr.
112	...do	1	4	13	1899	10-inch pipe	,066	1,066	577	CSGR	...do	...do	.....	.....	1.200	Irr.
113	...do	1	4	13	1899	10-inch pipe	1,069	1,069	505	CSGR	...do	...do	.....	.....	1.040	Irr.
114	...do	1	4	13	1900	10-inch pipe	1,079	1,079	478	CSGR	...do	...do	.....	.....	3.000	Irr.
115	Gage Canal Co	1	4	26	1891	10-inch pipe	1,033	1,033	656	.....	...do	...do	.....	.....	0.089	Irr.
116	...do	1	4	26	1891	10-inch pipe	1,034	1,034	534	.....	...do	...do	.....	.....	0.956	Irr.
117	...do	1	4	26	1891	10-inch pipe	1,034	1,034	582	.....	...do	...do	.....	.....	0.770	Irr.
118	...do	1	4	26	1891	10-inch pipe	1,034	1,034	482	.....	...do	...do	.....	.....	1.026	Irr.
119	...do	1	4	26	1891	10¼-inch pipe	1,034	1,034	320	.....	...do	...do	.....	.....	0.064	Irr.
120	...do	1	4	26	1891	10-inch pipe	1,034	1,034	784	.....	...do	...do	.....	.....	1.089	Irr.
121	...do	1	4	23	1888	10¼-inch pipe	1,036	1,036	196	.....	...do	...do	.....	.....	0.550	Irr.
122	...do	1	4	23	1888	10¼-inch pipe	1,036	1,036	190	.....	...do	...do	.....	.....	0.979	Irr.
123	...do	1	4	23	1889	10-inch pipe	1,036	1,036	142	.....	...do	...do	.....	.....	0.188	Irr.
124	...do	1	4	23	1889	10¼-inch pipe	1,036	1,036	148	.....	...do	...do	.....	.....	0.121	Irr.

[a] 1898. [b] 1891. [c] 1892. [d] 1900. [e] 1894. [f] 1898. [g] Not finished.

NOTE.—No. 48 is No. 335 of Redlands quadrangle; no record for Nos. 36, 40, 41, and 49; Nos. 50, 63, and 64 are Nos. 334, 336, and 337, respectively, of Redlands quadrangle; No. 46 is also in Redlands quadrangle.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner of well.	Location (T.R.S.).			Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S.	W.				Feet.	Feet.	Feet.						Sec.-ft.	
125	Gage Canal Co.	1	4	24	1886	7-inch pipe	1,037	1,037	141		Hard	Artesian			2.340	Irr.
126	do	1	4	13	1886	7-inch pipe	1,037	1,037	181		do	do			1.928	Irr.
127	do	1	4	13	1891	10-inch pipe	1,037	1,037	426		do	do			5.901	Irr.
128	do	1	4	13	1891	10-inch pipe	1,037	1,037	472		do	do			1.874	Irr.
129	do	1	4	13	1891	10-inch pipe	1,048	1,048	518		do	do			1.874	Irr.
130	do	1	4	13	1891	10-inch pipe	1,049	1,049	338		do	do			1.264	Irr.
131	do	1	4	13	1891	10-inch pipe	1,049	1,049	380		do	do			0.770	Irr.
132	do	1	4	13	1891	10-inch pipe	1,049	1,049	386		do	do			1.424	Irr.
133	do	1	4	13	1891	10-inch pipe	1,052	1,052	198		do	do			5.314	Irr.
134	do	1	4	13	1891	10-inch pipe	1,057	1,057	124		do	do			1.299	Irr.
135	do	1	4	13	1891	10-inch pipe	1,055	1,055	116		do	do			2.746	Irr.
136	do	1	4	13	1891	10-inch pipe	1,057	1,057	134		do	do			5.963	Irr.
155	do	1	4	13	1892	10-inch pipe	1,051	1,051	193		do	do			8.239	Irr.
156	do	1	4	13	1892	10-inch pipe	1,046	1,046	192		do	do			8.315	Irr.
157	do	1	4	13	1892	10½-inch pipe	1,044	1,044	390		do	do			4.835	Irr.
158	do	1	4	13	1892	10-inch pipe	1,042	1,042	224		do	do			5.697	Irr.
159	do	1	4	13	1885	7-inch pipe	1,045		123		(a)	(a)			1.923	Irr.
160	do	1	4	13	1885	7-inch pipe	1,045		133		(a)	(a)			0.473	Irr.
161	do	1	4	13	1885	7-inch pipe	1,045		133		(a)	(a)			3.015	Irr.
162	do	1	4	13	1885	5-inch pipe	1,048		139		(a)	(a)			8.217	Irr.
163	do	1	4	13	1885	7-inch pipe	1,048		211		(a)	(a)			4.641	Irr.
164	do	1	4	13	1885	7-inch pipe	1,046		100		(a)	(a)			0.579	Irr.
169	do	1	4	13	1890	10-inch pipe	1,037	1,037	300			Artesian			5.901	Irr.
170	Riverside Trust Co.	1	4	23	1900	10-inch pipe	1,011	1,011	582			do			6.131	Irr.
171	Bloomington Land Co.	1	5	22	1900	12-inch pipe	1,100	858	454	SGCR		do	$1,200			Not used.
172	D. Johnson	1	4	8		8-inch pipe	1,095	1,081	283		Soft		600			Not used.
173	Fox, Archibald & Lantz.	1	4	8			1,089					Centrifugal; 10 gas			0.414	Irr.
174	Jas. Lamb	1	4	8	1894	8-inch pipe	1,097	1,083	102		Soft	do	200	$1,800	0.400	Irr.
175	Jas. Barnhill	1	4	8		8-inch pipe	1,097					Centrifugal; 15 electric.			0.800	Irr.
176	City of Colton	1	4	8	1899	10-inch pipe	1,087	1,070	490		Soft	Centrifugal; electric			0.834	Irr; dom.
177	do	1	4	8	1899	8-inch pipe	1,084	1,068	90		do	do			0.200	Irr; dom.
178	G. W. Curtis	1	4	24	1895	7-inch pipe	1,088	1,063	85	SCG	Hard	8-wind	130	70	0.002	Irr; dom.
179	J. J. Curtis	1	4	24	1892	7-inch pipe	1,088	1,063	90		do	do	150	120	0.003	Irr; dom.
180	A. C. Harvey	1	4	24	1898	7-inch pipe	1,088	1,088	600	GC	do	Centrifugal; 12 gas	400	1,200	2.250	Irr.
181	W. A. Thomas	1	4	24			1,078	1,076				Artesian				
182	L. S. Dart	1	4	25	1890	7-inch pipe	1,075	1,055	80		Hard	12 wind	150		0.002	Dom.

188	Anderson estate	1	4	26		(8-inch pipe			450		Soft	Centrifugal; 25 gas		2,275	0.080	Irr.
						(4.5-inch pipe	1,009		160		Hard	Artesian	200		0.100	Irr; dom.
184	A. Hunt	1	4	27	1889	7-inch pipe	1,005	1,005	127			do	90		0.800	Irr.
185	do	1	4	27	1889	7-inch pipe	1,001	1,001	57			do	1,100		0.400	Irr.
186	do	1	4	27	1895	9½-inch pipe	1,004	1,004	280	SCG		do	500			Irr.
187	do	1	4	27	1894	7-inch pipe	1,007	1,007	200			do				
188	No record												150	100		Irr; dom.
189	E. M. Cooley	1	4	27	1889	7-inch pipe	1,019	959	98		Hard	12 wind			0.010	Dom.
190	H. L. Drew	1	4	21		3-inch pipe	980	980	200		do	Artesian	150	100		Dom.
191	C. C. Cooley	1	4	27	1895	7-inch pipe	998	928	85		do	12 wind	1,000		1.200	Irr.
192	P. Filance	1	4	27	1887	10-inch pipe	983	983	250		Soft	Artesian				
193	Filance estate	1	4	27	1890	3-inch pipe (3)	984	984	75 85 90		do	do			0.900	Irr; dom.
194	O. A. Byrne	1	4	21		2-inch pipe	984	980				Hand		5		Dom.
195	Harry Whaley	1	4	34	1890	7-inch pipe	1,150	1,115	100		Hard	8 wind			0.001	Dom.
196	Thomas N. Hunt	1	4	34	1890	D, 3 feet dia	1,117	1,000	123			16 wind	750	100		Dom.
197	Mr. Blair	1	4	34	1890	D, 5 by 5 feet	1,115	1,109	16			Never used				
198	Ignacio Reyes	1	4	34	1895	Dug	1,182	1,172	13		Soft		15	3		Dom.
199	Washington School	1	4	27		7-inch pipe	1,043	986	129			8 wind		90		Dom.
200	S. A. Pooles	1	4	33	1890	7-inch pipe	1,015	955	75		Hard	12 wind		500	0.006	
201	Fred Pooles	1	4	33	1884	7-inch pipe	955	907	52			8 wind				Dom.
202	Mrs. C. A. Peake	1	4	33	1880	2-inch pipe	950	936	18		Hard	Hand	10			Dom.
203	Chas. Green	1	4	33		3-inch pipe	944		3		do	Wind				Dom.
204	J. D. Warner	1	4	28	1884	1½-inch pipe	938	927	13		do	Hand	10			Dom.
205	do	1	4	28	1888	1½-inch pipe	926	916	13		do	do	8			Dom.
206	do	1	4	28	1894	10-inch pipe	941	935	515	GCR	do		2,455			
207	Geo. Cooley, sr	1	4	27	1894	7-inch pipe	978	952	72	G		12 wind		125	0.005	Irr; dom.
208	C. A. Poole	1	4	27	1900	7-inch pipe	1,002	984	50	SG	Hard	Hand	110			Dom.
209	A. A. Warren	1	4	33	1885	2-inch pipe	936	929	25		do	12 wind	15	150	0.002	Irr; dom.
210	W. Riverside Water Co.	1	4	32			950	944	112	GR	do	30 compressor		1,275		Irr.
211	J. M. Snodgrass	1	4	28	1898	D, 10 feet dia	931	927	13	GS	do	Bucket pump; eng	50	600	0.500	Irr.
212	do	1	4	28	1888	D, 2 feet dia	923	920	7.5	GS	do	12 wind	10	50	0.008	Irr.
213	A. A. Warren	1	4	33	1897	2-inch pipe	943	936	15		do	Hand	15	5		Dom.
214	S. P. R. R. Co	1	4	21	1892	7-inch pipe	958	915	45		do	12 wind			0.005	Dom.
215	Frank Parody	1	4	28	1900	Dug	955	934	33	S	do	Hand		12		Dom.
216	Martin Gahm	1	4	21	1888	D, 3 by 3 feet	964	927	41		do	8 wind	50	75	0.005	Dom.
217	W. H. Wells	1	4	21	1893	D, 2.5 by 2.5 feet	966	928	44	SG	do	Hand	6			Dom.
218	C. G. Turner	1	4	21	1895	7-inch pipe	966		70		do	12 wind				
219	G. B. Kinyon	1	4	21	1888	D, 3 by 3 feet	948	934	25		Soft	Wind	25	500		Irr; dom.
220	J. F. Stuchberry	1	4	21	1896	D, 3.5 by 3.5 feet	952	933	22	CSG	do	8 wind	30	90	0.007	Irr; dom.
221	J. H. Vaughan	1	4	21	1896	D, 4 feet dia	955	934	27		Hard	12 wind	48	75	0.009	Irr; dom.
222	Alfred Vaughan	1	4	21	1900	D, 4 feet dia	959	928	34			do	62	155		Irr.
223	W. L. Vaughan	1	4	21	1884	D, 4 feet dia	965		40		Hard	do			0.009	Irr; dom.
224	H. D. Young	1	4	21	1890	D, 2 feet dia	963	931	40		Soft	Hand	40			Dom.

[a] Wells 159 to 164 are connected. From this group a 40-horsepower gasoline engine and centrifugal pump raise 2.66 second-feet of water. These wells were artesian until 1900.

NOTE.—Flow of wells Nos. 104 to 114 and 170 was measured on completion of wells. Flow of wells Nos. 115 to 136 and 155 to 164 is given for October, 1892. No other records of flow of these wells. Wells Nos. 137 to 154 and 165 to 168 are in Redlands quadrangle, as are Nos. 391 to 412. Flow of these wells is given for October, 1892.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner of well.	Location (T. R. S.).	Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S. W.			*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
225	J. H. Dodson	1 4 21	1885	D, 4 feet dia	969	926	50		Soft	8 wind		$105	0.008	Irr; dom.
226	Henry Kaiser	1 4 21	1892	D, 4 feet dia	964	922	43		do	12 wind	$84		0.006	Irr; dom.
227	H. C. Dodson	1 4 21	1892	D, 2 feet dia	968	928	55		do	8 wind		212		Irr; dom.
228	John Benner	1 4 21	1880	D, 4 feet dia	970	916	62			12 wind			0.002	Irr; dom.
229	Tom Moran	1 4 21		D, 4 feet dia	974	921	54		Hard	Hand			Small.	Dom.
230	T. Allen	1 4 21	1880	D, 4 feet dia	978	924	68		Soft	14 wind		155	0.001	Dom.
231	S. A. Woodard	1 4 21	1882	D, 4.5 feet dia	984	928	69		Hard	12 wind			0.009	Irr; dom.
232	Los Angeles Bdg. Co.	1 4 21		D, 4 by 4 feet	1,000	Dry.	70			10 wind				
233	J. A. Coburn	1 4 16	1890	D, 4 by 4 feet	1,000	934	80		Hard	12 wind			0.005	Irr; dom.
234	Miss B. Top	1 4 16			1,038	1,038	3			8 wind	5	65	0.002	Irr; dom.
235	Byron Waters	1 4 16	1893	D, 9.5 by 9.5 feet and 5 by 5 feet.	1,019	991	28			Centrifugal; 3 electric.	300	376	0.6	Irr; dom.
235a	do	1 4 16	1889	3-inch pipe	1,019		220			Artesian	700		0.005	Irr; dom.
236	Dr. Rowl			Pipe						do				
237	do			Pipe					Sulph.	do				
238	Homer Jones	1 4 16	1895	3-inch pipe	1,023	1,010	300		do	8 wind			0.002	Irr; dom.
239	Mrs. M. G. Hammel	1 4 16			1,008	1,000	83		Hard	do		75	0.002	Irr; dom.
240	Riverside Trust Co	1 4 23		7-inch pipe	1,000				do	Hand				Dom.
241	F. S. West	1 4 23	1897	2-inch pipe	998									Irr; dom.
242	Mrs. E. A. Paine	1 4 22	1896	3-inch pipe	1,000	1,000	109	SCG	Hard	Artesian		75	0.04	Irr; dom.
243	M. B. Warren	1 4 22	1885	4-inch pipe	996	996	125		do	do			0.01	Irr; dom.
243a	do	50' SE. from 243	1899	3-inch pipe	997	997	180	SCG		do			0.25	Irr.
244	do	1 4 22	1880	2-inch pipe	998	998	125		Hard	do			0.041	Irr; dom.
244a	do	20' SW. from 244	1899	3-inch pipe	997	997			do	do			0.178	Irr; dom.
245	C. E. Bishop	1 4 23	1882	3-inch pipe	1,001	1,001	94		do	do	125		0.02	Irr; dom.
245a	do	1 4 23	1888	7-inch pipe	1,004	1,004	94	SC	do	do			0.02	Irr; dom.
246	Wm. E. Everett	1 4 22	1898	3-inch pipe	1,001	1,001	96		do	do	100		0.25	Irr; dom.
247	Bob Gomer	1 4 15	1890	3-inch pipe	984				do					
248	John Welsh	1 4 23		3-inch pipe	1,007	1,007	100		Hard	Artesian			0.088	Irr; dom.
249	S. B. Parish	1 4 14	1892	10-inch pipe	1,019	1,019	540		Soft	do	2,500		0.40	Irr.
250	do	1 4 14	1885	6-inch pipe	1,017	1,015	104		Hard		300			
251	do	1 4 14	1889	2-inch pipe	1,016		100		do		150			
252	do	1 4 14	1870	1¼-inch pipe	1,014	1,014	83		do	Artesian			0.004	
253	Mrs. Elizabeth Case	1 4 14	1898	3-inch pipe	1,007	1,007	91		do	do	85		0.115	Irr; dom.
254	do	1 4 14	1892	7-inch pipe	1,009	1,009	260		do	do	500		0.2	Irr.
254a	W. G. Merrilees	1 4 14	1893	7-inch pipe	1,009	1,009	211		do	do			0.14	Irr.
254b	do	1 4 14	1897	3-inch pipe	1,009	1,009	86		do	do			Small.	Irr.
255	Wm. Stewart	1 4 15	1898	8-inch pipe	1,004	1,004	315		do	do			[a]1.14	Irr.
256	do	1 4 15	1898	9-inch pipe	1,005	1,005	85		do	do			[b]0.2	Irr.

257	....do	1	4	15		1¼-inch pipe	1,004	1,004				...do	....do			Small.	Dom.
259	....do	1	4	15		7-inch pipe	1,002					...do					Irr.
260	John Sullivan	1	4	14	1874	2-inch pipe	1,021		82					100		(c)	Irr; dom.
261	....do	1	4	14	1893	3-inch pipe	1,024	1,024	210			Hard	Artesian	325		0.062	
263	....do	1	4	14	1884	7-inch pipe	1,025	1,023	84					80		(d)	
264	....do	1	4	14	1871	2-inch pipe	1,037		90							(d)	
265		1	4	14	1892	2-inch pipe	1,022		92				Artesian			0.002	Dom.
266	Wm. Baker	1	4	14	1870	1.5-inch pipe	1,022	1,022	96			Hard	....do	130		Small.	Dom.
267	....do	1	4	14	1899	3-inch pipe	1,024	1,024	271	SGC		...do	....do	435		0.178	Dom; irr.
268	P. J. Clevenger	1	4	14		2-inch pipe	1,030						10 electric; centrifugal.			(c)	
269	....do	1	4	14	1897	10-inch pipe	1,043		150							0.5	Irr.
270	Henry Warren	1	4	14	1883	2-inch pipe	1,033	1,023	106					150		(d)	Dom; irr.
271	....do	1	4	14	1890	3-inch pipe	1,033	1,023	100				12 wind	100	160	(d)	Dom; irr.
272	John Sullivan	1	4	14	1898	3-inch pipe	1,024	1,024	214			Hard	Artesian	300		0.178	Irr.
273	Henry Warren	1	4	14	1880	7-inch pipe	1,036	1,026	106					200		(e)	Not used.
274	....do	1	4	14	1880	7-inch pipe	1,038	1,028	220					500		(f)	Not used.
275	....do	1	4	14	1893	10-inch pipe	1,039	1,039	640				Artesian	3,000		0.386	Irr.
276	Frank Feri	1	4	14		2-inch pipe	1,034						Hand			(g)	Dom.
277	G. Renwick	1	4	8		6-inch pipe	1,090	1,055	186			Soft	8 wind			Small.	Dom.
278	Orange Land and Water Co.	1	4	8		7-inch pipe	1,089	1,089	225			...do	Centrifugal; 20 compressor; 3 wells in group together.			1.64	Dom; irr.
279	Callahan estate	1	4	20	1886	D, 4 by 4 feet	1,009	933	84				12 wind				
280	E. Memory	1	4	20	1886	D, 4 by 4 feet		982	927	60			Hard	....do			Small.	Dom.
281	F. A. Cleveland	1	4	8	1898	2-inch pipe	1,072		90				8 wind		47	40	Small.	Dom.
282	C. H. Westmyer	1	4	8	1897	3-inch pipe	1,089	1,082	94	GSC		Soft	....do	74	100	Small.	Dom; irr.
283	W. W. Brison	1	4	9	1899	2-inch pipe	1,062	1,052	99	SG		...do	10 wind	100	200	Small.	Dom.
284	G. F. Woods	1	4	9	1900	8-inch pipe	1,059	1,049	140			...do	....do	300	350	0.008	Dom; irr.
285	....do	1	4	9	1887	7-inch pipe	1,060	1,060	300							None.	
286	City of Colton	1	4	8		{10-inch pipe (2) / 7-inch pipe (2)}	1,085		{200-640}				{Centrifugal; 20 electric.}		2,000	2.500	Dom; irr.
287	Isaac Jameson	1	4	8	1898	8-inch pipe	1,070	1,050	90			Hard	12 wind	126	275	0.015	Dom; irr.
288	J. Collins	1	4	8	1887	3-inch pipe	1,054		75				10 wind			Small.	Irr; dom.
289	J. C. Ralphs	1	4	9	1899	10-inch pipe	1,047	1,016	202			Soft	12 wind	500	200	Small.	Irr; dom.
290	Los Angeles Bdg. Co.	1	4	9	1893	10-inch pipe	1,052		160			...do	8 gas; centrifugal			0.8	Irr.
291	V. Herkelrath	1	4	15	1882	2-inch pipe		979	979			...do	Artesian	70		0.072	Dom.
292	....do	1	4	15	1880	2-inch pipe		980	980			...do	....do	175		0.119	Irr.
293	Mrs. Nowland	1	4	15	1875	2-inch pipe		980	980	160			....do	275			Irr.
294	M. H. Hurd	1	4	15	1887	2-inch pipe		983				Hard	....do				Dom.
295	Mrs. N. H. Ball	1	4	15	1894	7-inch pipe		996	996	253		Soft	....do	500		0.262	Irr.
296	Los Angeles Bdg. Co.	1	4	9		10-inch pipe	1,051	1,049	446				....do			0.4	Irr.
297	....do	1	4	9		10-inch pipe	1,050	1,048	451				....do			0.4	Irr.
298	Mrs. N. H. Ball	1	4	15	1886	3-inch pipe		992	992	107		Soft	....do	250			Dom.
299	W. Beck	1	4	15	1892	3-inch pipe		998	998	204		...do	....do				Irr.
300	H. Klueter	1	4	10	1885	3-inch pipe	1,006	1,006	200			...do	....do	300		0.074	Dom; irr.
301	....do	1	4	10	1887	3-inch pipe	1,005	1,005	206			Soft	....do	328			Irr.
302	....do	1	4	10	1887	3-inch pipe	1,005	1,005	132			...do	....do	159		0.518	Irr.
303	....do	1	4	10	1897	3-inch pipe	1,003	1,003	135			...do	....do	125		0.006	Irr.

[a] 1899.
[b] 1898.
[c] Stopped flowing in 1895.
[d] Stopped flowing in 1898.
[e] Stopped flowing in 1889.
[f] Stopped flowing in 1890.
[g] Stopped flowing in May, 1900.

NOTE.—No record for Nos. 258 and 262.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner of well.	Location (T.R.S.).	Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S. W.			*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
304	Stephen Wood	1 4 11	1894	3-inch pipe	1,010	1,010	160		Soft	Artesian			Small.	Dom.
305	W. B. Barton	1 4 14	1883	2-inch pipe	1,041		100		do	12 wind		$216	Small.	Dom.
306	Stephen Wood	1 4 11	1890	3-inch pipe	1,022		164			8 wind			Small.	Stock.
307	F. M. Keller	1 4 11	1892	3-inch pipe	1,024	1,024	267		Soft	Artesian	$500		0.02	Dom.
308	W. B. Barton	1 4 13	1892	10-inch pipe	1,045	1,033	115		do	9 gas; centrifugal			0.200	Irr.
309	A. J. Downer	1 4 13	1889	3-inch pipe	1,045		190		do	12 wind	125	50	Small.	Dom.
310	Edwin Martin	1 4 13		3-inch pipe	1,045	1,033	215		do	Hand			Small.	Dom.
311	Lucas Hoagland	1 4 13	1876	2-inch pipe	1,049	1,039	80		do	do	75		Small.	Dom.
312	do	1 4 13	1884	3-inch pipe	1,050	1,040	250		do	8 wind	250	75	Small.	Stock.
313	do	1 4 12	1884	2-inch pipe	1,047		100		do		100			Not used.
314	R. F. Garner	1 4 10	1888		1,019		200			Artesian			Small.	Dom.
315		1 4 12		10-inch pipe	1,059	1,059	682+			do			0.123	Stock.
		N. W.												
316	Geo. M. Cooley	1 4 36	1892	7-inch pipe	1,150	1,108	66		Soft	12 wind		500		Irr; dom.
317	do	1 4 36	1895	11-inch pipe	1,150	1,108	80			9 gas		1,500	0.6	Irr.
317a	do	1 4 36	1895	10-inch pipe	1,150	1,108	80			9½ cylinder pumps				Irr.
318	E. J. Stiles	1 4 35	1898	7-inch pipe	1,196	1,157	48		Soft	10 wind	40	160	Small.	Dom; st.
319	Jas. Dickson	1 4 35	1898	10-inch pipe	1,179	1,145	44		do	12 wind		135	Small.	Dom.
320	J. G. Wood	1 4 35	1894	7-inch pipe	1,124	1,090	44		do	do		300	Small.	Dom.
321	do	1 4 36	1895	11-inch pipe	1,140	1,092	64		do	Cylinder pump; 5 gas	240	600	0.125	Irr.
322	M. E. Myers	1 4 35	1890	2-inch pipe	1,111	1,089	310		Hard	12 wind				Dom; irr
		S. W.												
323	J. S. Bean	1 4 3	1889	3-inch pipe	1,108	1,108	210			Artesian	200		0.1	Irr.
324	do	1 4 3	1898	10-inch pipe	1,108	1,108	524		Hard	do	1,100		0.9	Irr.
		N. W.												
325	J. F. Johnson	1 4 34	1890	7-inch pipe	1,098	1,076	39		do	Hand				Not used.
326	Oscar Perris	1 4 26			1,177		96			Steam; power				Irr.
327	S. G. Ramsey	1 4 25	1896	10-inch pipe	1,190	1,125	90	SC		Power; 10 gas	160	1,200	0.3	Irr.
328	Saml. S. Ford	1 4 26	1898	D, 3 feet dia	1,185	No water.	58			Wind		225	None.	
329	Mescupiabe L. & W. Co.	1 4 23	1899	7-inch pipe	1,288	1,143	402		Hard	Power; 15 gas	1,200	2,000	0.5	Dom; st; irr.
330	do	1 4 26	1892	7-inch pipe	1,222	No water.	102			Wind	300	250	None.	
331	Mrs. Anne C. Severance.	1 4 26	1895	7-inch pipe	1,227	No water.	106			12 wind	300	900	None.	
332	Mrs. S. A. Smith	1 4 27	1894	7-inch pipe	1,224	1,124	140		Soft	16 wind		800	0.010	Irr; dom.
333	F. M. Johnson	1 4 34	1899	10-inch pipe	1,117	1,095	600			10 gas; cylinder pump.	1,100	800	0.220	Irr.
334	do	1 4 34	1890	12-inch pipe	1,112	1,084	40			Wind			Small.	St; dom.

335	H. H. Fitting	1	4	35	1885	7-inch pipe	1,124		44		Soft	do			Small.	St; dom
336	do	1	4	35	1888	D, 6 by 6 feet	1,125	No water.	47			4½ gas; cylinder pump.	100	500	None.	
337	do	1	4	35	1886	3-inch pipe	1,131		325				1,000		Dry.	
338	C. Hansen	1	4	35	1895	7-inch pipe	1,127	1,080	39		Soft	8 wind		200	Small.	St; dom.
339	N. Hoien	1	4	35	1895	7-inch pipe	1,127	1,080	47		do				Small.	St; dom.
340	John Anderson	1	4	34	1895	7-inch pipe	1,130		90		do	8 wind	114	100	Small.	St; dom.
341	H. N. Stones	1	4	34	1884	7-inch pipe	1,141	1,087	85		do	do		125	Small.	St; dom.
342	M. F. Swing	1	4	34	1891	7-inch pipe	1,151		93		do	12 wind		220		St; dom.
343	do	1	4	34	1894	7-inch pipe	1,152		87		do	do			Small.	Irr.
344	A. R. Togg	1	4	34	1891	7-inch pipe	1,160		100		do	do				Irr; dom.
345	F. L. Smith	1	4	34	1897	7-inch pipe	1,163		106		do	10 wind	105	135	0.002	Irr; dom.
346	John W. Anderson	1	4	34	1880	7-inch pipe	1,165	1,103	70		do	do	75	175	0.002	Irr.
347	do	1	4	34	1900	7-inch pipe	1,166	1,103	113		do	16 wind	125	225	0.004	Irr.
348	S. E. Pearson	1	4	27	1899	7-inch pipe	1,182	1,107	104		do	12 wind	135	60	Small.	Irr; dom.
349	R. Meacham	1	4	27	1900	7-inch pipe	1,183		110		do	do			Small.	Irr; dom.
350	do	1	4	27	1890	7-inch pipe	1,172	No water.	64			do			None.	
351	J. H. Taylor	1	4	27	1896	7-inch pipe	1,188	No water.	62		Soft	8 wind	50	100	None.	
352	W. G. Warner	1	4	27	1899	7-inch pipe	1,189	1,119	80			10 steam				Not used.
353	F. D. Olmstead	1	4	27	1895	7-inch pipe	1,190		101		Soft	12 wind		100	Small.	Irr; dom.
354	S. F. Kelley	1	4	28	1897	7-inch pipe	1,170	1,121	115		Hard	8 wind			Small.	Irr; dom.
355	S. F. Kelley et al	1	4	28	1900	12-inch pipe	1,185	1,127	208			(20) electric; centrifugal.	1,700	1,171	0.9	Irr.
355a	do	1	4	28	1899	10-inch pipe	1,185	1,127	440							
356	H. C. Ward	1	4	28		7-inch pipe	1,177	1,118	120			12 wind			Small.	Irr.
357	S. H. Johnson	1	4	28	1885	7-inch pipe	1,182	1,122	84		Soft	10 wind		250	Small.	Dom.
358	H. Giddings	1	4	28	1898	7-inch pipe	1,205	1,148	73		do	15 wind		125		Dom.
359	W. G. Rowland	1	4	28	1893	7-inch pipe	1,224	1,150	112		Hard	Geared pump; 8 gas	125	625	0.1	Irr.
360	Fred. Heilemann	1	4	32	1889	7-inch pipe	1,227	1,147	148		do	16 wind	200	750	0.008	Irr; dom.
361	do	1	4	32	1894	7-inch pipe	1,228	1,148	129		do	18 wind			0.012	Irr; dom.
362	do	1	4	29	1890	10-inch pipe / 8-inch pipe / 6¾-inch pipe	1,245	1,155	1,025				7,000		(a)	
363	B. E. Wheeler	1	4	29	1898	10-inch pipe	1,258	1,152	125		Hard	Plunger pump; 5 gas	300	800		Irr; dom.
364	F. Alvarado	1	4 S. W.	32	1900	7-inch pipe	1,188	1,135	93							Not used.
365	A. B. Hancock	1	4	5	1896	7-inch pipe	1,170		56		Hard	12 wind	125	100	Small.	Dom; etc.
366	do	1	4	5	1892	7-inch pipe	1,160		56		do	do				Dom; etc.
367	D. W. White	1	4 N. W.	4	1871	7-inch pipe	1,109	1,089	195			Gas; centrifugal; 8 wind.	1,200	200	0.400	Irr; dom.
368	W. F. Holcomb	1	4 S. W.	33		7-inch pipe	1,115	1,089	37		Soft				Small.	Dom.
369	Alex. Wixom	1	4 N. W.	4	1899	8-inch pipe	1,117		45		Hard	12 wind	50	148	Small.	Dom.
370	F. L. Holcomb	1	4	33	1885	7-inch pipe	1,128	1,100	47		do	do	100	150	Small.	Dom.
371	do	1	4 S. W.	33	1885	7-inch pipe	1,133	1,103	47		do	do	100	150	Small.	St.
372	J. J. Whitney	1	4	4	1884	Pipe	1,129	1,101	112		do	Wind		400	Small.	Dom; st.
373	P. B. Hockaday	1	4	4	1897	7-inch pipe	1,133		110		Soft	12 wind		500	Small.	Dom; irr.
374	J. J. Morris, sr	1	4	5	1890	8-inch pipe	1,137	1,109	53		do	10 wind		75	Small.	Dom; irr

[a] Tools left in well.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner of well.	Location (T.R.S.).	Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S. W.			*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
375	Dexter Field	1 4 5 N. W.	1870	6-inch pipe	1,147	1,112	45		Hard	10 wind			Small.	Dom.
376	C. A. Muscott	1 4 32	1886	8-inch pipe	1,158	1,115	78		Soft	12 wind	$100	$250		Dom; irr.
377	J. W. Roberts	1 4 27	1899	10-inch pipe	1,210	1,155	160	GC	do	Plunger pump; 5 electric.	400	900	0.24	Dom; irr.
378	T. C. Parker	1 4 32	1886	Pipe	1,205		98		Hard	12 wind; 3 gas		550		Dom; irr.
379	P. Oldecker	1 4 33	1893	7-inch pipe	1,195		133		do	Geared pump; 2 gas		400	0.10	Dom; irr.
380	A. Peterson	1 4 33	1890	7-inch pipe	1,192	1,134	70	SG	Soft	12 wind	50	100	Small.	Dom; irr.
381	C. A. Bruckman	1 4 32	1894	10-inch pipe	1,221	1,151	146		do	Geared pump; 16 gas	325	775	0.36	Irr.
382	do	1 4 32	1892	7-inch pipe	1,215	1,145	84	SCG	do	12 wind	115	300		Irr.
383	do	1 4 32	1892	7-inch pipe	1,214	1,144	85		do	Geared pump; 5 gas	115	625	0.042	Irr.
384	do	1 4 32	1890	7-inch pipe	1,192	1,134	85		do	12 wind	115	250	Small.	Dom.
385	Wilson & Wheat	1 4 32	1890	7-inch pipe	1,188	1,128	82		do	16 wind				Dom; irr.
386	E. D. Palmer	1 4 33	1894	7-inch pipe	1,184		80		Hard	14 wind			Small.	Dom; irr.
387	C. G. Leonhardt	1 4 32	1890	7-inch pipe	1,182		85		Soft	12 wind	115	192	Small.	Dom; irr.
388	do	1 4 32	1899	8-inch pipe	1,197	1,133	90			do	125	297	0.006	Irr.
389	S. E. A. Palmer	1 4 33	1897	7-inch pipe	1,176	1,124	92		Hard	14 wind	150	350	0.003	Dom; irr.
390	Fred F. Palmer	1 4 33	1899	D, 4 by 6 feet; 7-inch pipe	1,189	1,134	85		do	Duplex; steam	300	500	0.036	Irr.
391	W. D. Wilson	1 4 32	1893	8-inch pipe	1,203	1,138	94		do	12 wind				Irr.
392	S. H. Harmon	1 4 32	1893	10-inch pipe	1,194	1,132	133		do	Geared pump; 5 gas	1,300	(a)	0.020	Irr.
393	S. W. Harmon	1 4 32	1892	7-inch pipe	1,181	1,128	75		do	12 wind	50	220		Dom; irr.
394	J. O. Slatter	1 4 33	1890	7-inch pipe	1,155		100		Soft	do		150	Small.	Dom.
395	C. N. Damron	1 4 33		7-inch pipe	1,120	1,063	47		Hard	8 wind			Small.	Dom.
396	Mrs. Amy McCrary	1 4 33	1899		1,138	1,112	91		Soft	Hand			Small.	Dom.
397	Thos. Webster	1 4 33	1898	7-inch pipe	1,134					12 wind				Dom.
398	N. M. Swarthout	1 4 33	1895	7-inch pipe	1,142	1,115	75		Hard	8 wind	150	100	Small.	Dom.
399	do	1 4 33	1895	10-inch pipe	1,109		80			Horse	100	35	Small.	Irr.
400	J. H. Lytle	1 4 33	1895	7-inch pipe	1,166	1,135	79		Hard	12 wind	75	50	Small.	Dom; irr.
401	H. S. Davidson	1 4 33	1890	7-inch pipe	1,158		56		Hard	do		500		Dom; irr.
402	N. Swarthout	1 4 33	1895	7-inch pipe	1,142	1,108	55		do	8 wind			Small.	Dom.
403	G. W. Evans	1 4 33	1897	6-inch pipe	1,128	1,068	75		do	do			Small.	Dom.
404	R. M. Bradley	1 4 33	1894	7-inch pipe	1,101	1,082	90			12 wind			Small.	Dom.
405	Mrs. Sarah Abel	1 4 33	1890	D, 3 feet dia	1,109	1,088	22		Soft	Bucket			Small.	Dom.
406	R. Poppett	1 4 34	1895	7-inch pipe	1,109	1,085	45			12 wind	50	140	Small.	Dom; irr.
407	G. Johnson	1 4 34	1890	7-inch pipe	1,114	1,087	47		Hard	8 wind	60	60	Small.	Dom; irr.
408	E. G. Fish	1 4 34	1899	2-inch pipe	1,133		425		do	do	1,000		Small.	Dom; irr.
409	C. Cohn	1 4 34		7-inch pipe	1,118	1,089			Soft	10 wind			Small.	Dom.
410	O. B. Peck	1 4 34	1898	7-inch pipe	1,147		115		do	14 wind			Small.	Dom; irr.
411	K. P. Stephens	1 4 34	1893	7-inch pipe	1,104	1,114	66		do	do			0.010	Dom; irr.

412	Jno. Y. Anderson	1	4	34	1900	8-inch pipe 12-inch pipe	1,165	1,109	150 460				2,000			Not used.
413	Jno. Lawrence	1	4	34	1897	7-inch pipe	1,091	1,076	42		Soft	8 wind		160	Small.	Dom.
414	J. C. Wees	1	4	34	1898	7-inch pipe	1,097	1,073	46		do	do				Dom.
415	Thos. J. Rennous	1	4	34	1900	7-inch pipe	1,133	1,101	72		do	10 wind	72	150	Small.	Dom; irr.
416	H. H. Ham	1	4	34	1888	7-inch pipe	1,121	1,090	52		Hard	8 wind	75	100	Small.	Dom; irr.
417	W. M. Jenkins	1	4	34	1884	7-inch pipe	1,118	1,088	52			12 wind			Small.	Dom; irr.
418	Oscar Wees	1	4	34	1885	7-inch pipe	1,108		48		Soft	8 wind			Small.	Dom.
419	M. W. Davis	1	4	34	1898	7-inch pipe	1,100		42		do	do	40	90		Dom.
420	P. W. Heap, jr	1	4	34	1894	7-inch pipe	1,128	1,088	58		do	12 wind	60	125	0.002	Dom; irr.
421	B. M. Wall	1	4	34	1897	8-inch pipe	1,100		137		Hard	8 wind			Small.	Dom; irr.
		S. W.														
422	E. Case	1	4	3	1899	8-inch pipe	1,086	1,073	50		Soft	Hand			Small.	Dom.
423	Jno. E. Garner	1	4	2	1900	8-inch pipe	1,087	1,073	334			Centrifugal; 8 gas	750	750	0.800	Irr; etc.
		N. W.														
424	do	1	4	35	1888	10-inch pipe 7-inch pipe	1,164	1,108	420		Hard	Centrifugal; 20 electric.	1,500	3,000	1.200	Irr.
425	Colton City Water Co.	1	4	31	1900	10-inch pipe	1,202		208			Centrifugal; 25 gas			1.480	Irr; dom.
426	San Bernardino City Waterworks.	1	5	36	1895	2 11-inch pipes			320							
					1900	12-inch pipe	1,239	1,207	550 800		Soft	Centrifugal; 25 gas			1.400	City supply.
427	Riverside-Highland Water Co.	1	4	31	1900	10-inch pipe	1,218	1,204	320							Not used.
428	do	1	5	36	1892	10-inch pipe	1,246	1,211	650			Centrifugal; 22 gas	5,000	1,100	1.600	Irr; dom.
429	do	1	4	31	1898	2 10-inch pipes	1,250	1,201	350 300			Centrifugal; 30 electric.	3,000	2,500	2.000	Irr; dom.
430	do	1	4	31		2 10-inch pipes	1,258	1,208	500-600			do	3,000	2,500	2.800	Irr; dom.
431	Rialto Irrig. Dist. Citizens' Water Co	1	5	36	1891	2 10-inch pipes	1,255	1,204	450		Hard	Centrifugal; turbine	1,500		1.300	Irr; dom.
432	do	1	5	36	1894	10-inch pipe	1,260	1,207	460			Centrifugal; 20 gas	1,800	6,000	0.720	Irr; dom.
433	F. E. Watkins	1	5	36	1888	10-inch pipe	1,266	1,210	621		Soft	2 25 compressors			0.890	Irr.
434	Lytle Creek Water and Imp. Co.	1	5	36	1900	3 12-inch pipes	1,290	1,215	226	Gravel	do	Duplex steam	3,661	3,500	[b]2.200	Irr.
435	Rialto Irrig. Dist.	1	5	25	1897	10-inch pipe	1,333	1,303	520			Centrifugal; 30 electric.	1,500	2,000	1.800	Irr; dom.
436	do	1	5	25	1894	10-inch pipe	1,342	1,306	432		Hard	do	1,500	2,000	1.500	Irr; dom.
437	Anglo-American Canaigre Co.	1	5	25	1899	D, 7 by 9 feet (2)	1,337	1,307	45							Not used.
438	F. E. Watkins	1	5	25	1898	10-inch pipe	1,390	1,251	381				2,000			Not used.
439	Riverside-Highland Water Co.	1	4	31		20 wells	1,200-1,225								[c]	Irr.
		S. W.														
440		1	4	4		D, 4 by 4 feet	1,089	1,083	7			Hand				Stock.
441	M. E. Brooks	1	4	5	1886	3-inch pipe	1,102		132		Hard	8 wind				Dom; st; irr.
442	do	1	4	5		3-inch pipe	1,105		140			12 wind			Small.	Irr.
443	Mrs. Mary Bemis	1	4	5	1888	Pipe	1,113		132		Hard	Hand			Small.	Dom.
444	A. W. Bemis	1	4	5	1890	8-inch pipe	1,118	1,101	48		Soft	12 wind			Small.	Dom.
445	do	1	4	5	1894	10-inch pipe	1,114	1,104	50			Centrifugal; 3 gas		250	0.014	Irr.
446	D. F. Probst	1	4	4	1896	7-inch pipe	1,085	1,070	36		Soft	10 wind			Small.	Dom.
447	Mrs. A. Tompkins	1	4	5	1882	7-inch pipe	1,115		212		do	Wind	1,000	175	Small.	Dom; irr.

[a] Included in cost of well.

[b] Two wells.

[c] These 20 wells have nearly all ceased flowing.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner of well.	Location (T. R. S.).			Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S.	W.				*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
448	J. Hancock	1	4	5	1875	7-inch pipe	1,138	1,092	128		Hard	Wind			Small.	Dom; irr.
449	M. D. Reynolds	1	4	5	1900	10-inch pipe	1,136	1,106	146		Soft	Centrifugal; 25 gas	$300	$1,400	0.027	Irr.
450	do	1	4	5	1898	7-inch pipe	1,116	1,094	40		do	8 wind	60	150	Small.	Dom.
451	Mrs. M. Lord	1	4	4	1888	3-inch pipe	1,125		150		Hard	10 wind			Small.	Dom.
452	John Marshall	1	4	5	1888	7-inch pipe	1,128	1,103	42		Soft	do			Small.	Dom.
453	I. W. Hazlett	1	4	4	1900	7-inch pipe	1,101	1,082	142		Hard	12 wind	233		0.002	Dom.
454	Mrs. Alice Wixom	1	4	4	.....	7-inch pipe	1,097	1,055	42		Soft	do			Small.	Dom.
455	Mrs. Irving	1	4	4	.....	7-inch pipe	1,099	1,078	100			8 wind			Small.	Dom.
456	J. B. Kitring and R. H. Hacker.	1	4	4	1895	2-inch pipe	1,085	1,070 in 1899.	152		Hard	do		200	Small.	Dom.
457	J. F. Cadd	1	4	4	1888	7-inch pipe	1,088	1,057	40		do	Hand	40		Small.	Dom.
458	H. E. Gardner	1	4	5	.....	3-inch pipe	1,089	1,075			Soft	8 wind			Small.	Dom.
459	Mrs. Marilla Smith	1	4	5	1889	2-inch pipe	1,094	1,079	102		do	Wind	122	150	Small.	Dom.
460	San Bernardino County Hospital.	1	4	8	1898 1899	3-inch pipe 7-inch pipe 10-inch pipe	1,089	1,071	125 125 330		do	Centrifugal; 6 gas			0.300	Irr.
461		1	4	8	.....	2 wells	1,057					Electric				Irr.
462	Riverside Trust Co	1	4	26	.....	9 wells	1,019	1,019				Artesian				Irr.
463	Riverside Water Co	1	4	2	.....		1,036	1,036				do			1.976	Irr.
464	do	1	4	2	.....		1,037	1,037				do			1.980	Irr.
465	do	1	4	2	1900	10-inch pipe	1,040	1,040	544			do			2.896	Irr.
466	do	1	4	2	1900	10-inch pipe	1,041	1,041	582	CSG		do			3.096	Irr.
467	E. D. Meissner	1	4	26	1899	10-inch pipe 8-inch pipe	1,200	1,120	500	GC		Plunger pump; 20 gas	2,000	1,850	0.200	Irr.
468	G. G. Lathrop	1	4	26	1897	7-inch pipe	1,063	1,017	70	GC	Hard	10 wind	105	130	0.003	Dom; irr.
469	R. L. Dewitt	1	4	26	1897	Dug	1,047	1,028	26	LC	do	Hand				Dom.
470	Charles Morris	1	4	25	1892	D, 12 by 12 feet, 10-inch pipe.	1,078	1,063	80	SGC	do	12 wind	400	140	0.007	Irr.
471	do	1	4	26	1899	10-inch pipe 8-inch pipe 7-inch pipe	1,077		640	SGC	do	Artesian	1,500		0.006	
472	No record															
473	F. S. Waters	1	4	23	1877	2-inch pipe	1,054	1,044	196		Hard	8 wind	200	145	0.002	Dom; irr.
474	J. H. Hatherley	1	4	23	1888	3-inch pipe	1,555		450			Artesian	1,700		0.140	Irr.
475	J. H. Kelly	1	4	23	1890	8-inch pipe	1,089		362		Hard	do	2,000		0.400	Dom; irr.
476	do	1	4	23	1891	7-inch pipe	1,074	+1,066	500		do	Hand		5		Dom.
477	Mr. Myers	1	4	25	1890	7-inch pipe	1,080		400		do				(a)	
478	W. E. Pedley	1	4	2	1899	10-inch pipe	1,042		510	GR	Soft	Artesian	1,284		2.700	Irr.

MANUFACTURE OF PORTLAND CEMENT IN SOUTHERN CALIFORNIA.

An important element in the development of an irrigation community is the cost and use of hydraulic cement. Prior to 1893 all of the cement used in southern California came from Europe. This meant a serious financial drain on this section, and the building of a cement-manufacturing plant near Colton which reduced the cost of Portland cement 25 per cent and also kept the remaining 75 per cent at home was therefore an important event in irrigation development as well as building.

The plant of the California Portland Cement Company is three-fourths of a mile from the town of Colton. The company manufactures Portland cement, lime, marble dust, and crushed rock. It employs 70 men, and the capacity of the plant is 300 barrels of cement or 500 barrels of lime daily and an unlimited output of crushed rock. This Portland cement has been extensively used in the various irrigation and hydraulic-power systems of southern California, and has been pronounced by engineers to be equal to imported cement, while it is sold at a much lower price than the foreign article. C. W. Smith, of Pasadena, is now the president of the company and E. Duryee is the chemist.

Probably few, even in the engineering profession, would be inclined to credit the statement, which nevertheless can be corroborated by United States Government reports, that 75 per cent of the Portland cement consumed in the United States during 1900 was manufactured in this country. The only Portland-cement plant on the Pacific coast, however, is the one at Colton, where rotary kilns are in operation. At the outset the Colton company employed an expert to investigate the cement works in the East, of which there are many, and they adopted, as the result of his investigations, what they believe to be the best process. The plant is continuous and largely automatic in operation, machinery being employed to such an extent that 3 barrels of cement per day are obtained for each man employed, as contrasted with 1 barrel per day per man, the ordinary output in European works. The process is protected by letters patent and is American in every respect. The works are very favorably located, being in the center of the semitropical fruit belt of southern California and contiguous to most of the extensive irrigation and hydraulic-power plants of that section, thus insuring an increasing market for the product in the future. In the rear of the mill towers Slover Mountain, with its inexhaustible deposit of pure calcspar and two clay deposits at short distances, which provide abundant crude materials. The company is fortunate in having available limestone almost chemically pure and a clay peculiarly adapted to the manufacture of the cement, while the Los Angeles petroleum provides a cheap and excellent fuel. These advantages

enable the company to manufacture its product at a minimum cost and to place it on the market for about three-fourths the price of foreign cements. The mixing, grinding, and burning of the crude materials is carried on under the constant direction and analysis of a chemist whose laboratory is at the works. The crude materials are first crushed and mixed by weight, then ground to an impalpably fine powder, then fed continuously at the rate of 3 tons hourly into a rotary kiln 75 feet long, in which they remain one and three-fourths hours. The low heat of the upper end of the kiln drives off the moisture from the raw mixture; the low red heat of the middle part decarbonizes the limestone; and the high heat of the lower end causes the caustic lime alumina and silica to unite and form Portland cement clinker—little nodules the size of beans and walnuts. After leaving the kiln the clinker is cooled and ground into the finished product. The materials enter the kiln as a mechanical mixture of limestone and clay and come from it a chemical compound of definite formulæ.

The character of the Colton cement is the same as that of all Portland cements. Analyzed it approximates some of the leading foreign brands, while the physical tests have generally shown it to be superior to the foreign brands in the local market both in the fineness of the powder and in its tensile strength.

Analyses of Portland cements.

Constituent.	Colton, American (E. Duryee, analyst).	White Bros., English (E. Duryee, analyst).	Alsens, German (W. MacClay, analyst).
	Per cent.	*Per cent.*	*Per cent.*
Silica (SiO_2)	22.060	23.567	24.90
Alumina (Al_2O_3)	9.310	10.020	11.22
Ferric oxide (Fe_2O_3)	3.090	3.080	
Magnesia (MgO)	0.900	1.067	0.38
Lime (CaO)	61.512	59.000	59.98
Sulphuric acid (SO_3)	1.200	1.400	0.86
Alkalies	1.761	2.100	0.50
Moisture and carbonic acid			2.16
Total	99.833	100.234	100.00

The following table comprises data from the report of Mr. J. W. Robinette, C. E., the cement tester, who sampled and tested 4,000 barrels of the product purchased by the San Gabriel Electric Company:

Results of tests of Colton Portland cement.

Length of time.	Number of tests.	Average tensile strength.	Fineness passed.	Average of 4,000 barrels.
		Pounds.	*Mesh.*	*Per cent.*
1 day	255	129	2,500	99.64
7 days	510	510	8,100	95.37
28 days	481	607	144,000	93.22

The extreme care taken to insure a good and uniform cement may be inferred from the fact that the raw mixture is every half hour subjected to chemical tests for the determination of the percentage of lime, which element is not permitted to vary either way more than 1 per cent from the standard. The mixture is ground so fine that only one-third of 1 per cent remains on a 50-mesh screen, 5 per cent on a 90-mesh screen, and 7 per cent on a 120-mesh screen. After it has been burned the clinker is spread in layers on a cooling and mixing floor, and the accumulated burn of several days is thoroughly mixed before it is ground. After the cement has been ground and again mixed in conveyers and elevators it is put into sacks holding 95 pounds each. A sample is taken from every tenth sack and numbered. These samples are tested, a record of the tests being kept and embodied in the reports which are mailed to the purchasers.

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